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ABSTRACT

Measured length distributions of Atlantic herring (*Clupea harengus*) were not identical between midwater trawl catches from the fall systematic herring survey and bottom trawl catches from the fall stratified-random survey conducted by the Northeast Fisheries Science Center (NEFSC) from 1998 to 2012. The Scantrol FishMeter fish measurement board was used during the stratified-random bottom trawl survey, while the Ichthystick II Electronic Fish Measuring Board was used during the systematic herring survey. Both sets of measurements were recorded by the Fisheries Scientific Computing System (FSCS). We investigated whether differences in length-measurement systems caused discrepancies in length distributions between the 2 surveys. Our initial concern was that the Scantrol board may have rounded up to the nearest 0.5 centimeter on measurement and that on recording into FSCS the measurement was again rounded up to the nearest whole centimeter. In the first set of measurements, dowels were cut to known lengths, randomized, measured with each board, and recorded into FSCS. Three different measurement boards of each type were compared to assess variability within each board type. The actual board measurements and the recorded FSCS values were compared against the known values. Systematic biases were observed in 2 of the Scantrol boards, prompting a series of systematic measurements on all Scantrol boards. All fish lengths stored in FSCS from Scantrol boards were positively biased by 0.25 cm, and some boards appear to have a mechanical offset that can increase the bias up to 0.50 cm when compared to true lengths. We cannot completely rule out instrument error as the cause of discrepancies in mean Atlantic herring lengths between surveys, but the effects of rounding by the Scantrol boards and FSCS do not appear to explain the magnitude of the differences. Biological and sampling factors should be investigated as the cause of length distribution discrepancies between surveys.

INTRODUCTION

Length distributions of Atlantic herring (*Clupea harengus*) were not identical between midwater trawl catches from the fall systematic herring survey (Jech and Michaels 2006; Jech and Stroman 2012; Jech and Sullivan 2014) and bottom trawl catches from the fall stratified-random survey (Azarovitz 1981) conducted by the Northeast Fisheries Science Center (NEFSC) during 1998 to 2012 (Figure 1). In general, mean fork lengths from the stratified-random survey were longer than from the systematic herring survey in 10 of the 15 years, with magnitude of the differences ranging from 0 to 2 cm (Figure 2). Differences in herring lengths between the 2 surveys could be due to differences in survey design and timing, capture efficiencies among trawl gear, growth or spatial distribution, or measurement instrumentation. The systematic herring survey and stratified-random survey each used different electronic measurement boards to record fish fork length (FL). Because each survey used different measurement systems, in order to compare length measurements between the surveys we needed to determine whether differences in measurement instrumentation could account for the length discrepancies.

During the stratified-random survey, Scantrol (Scantrol AS, Sandviksboder 1c, 5035 Bergen, Norway) FishMeter fish measurement boards were used to measure fish lengths. The Scantrol boards were set to output lengths in centimeters to the nearest 0.50 cm, e.g., lengths between 9.75 and 10.249 cm recorded as 10.0 cm, lengths between 10.25 and 10.749 cm recorded as 10.5 cm, lengths between 10.75 and 11.249 cm recorded as 11.0 cm, and so on (Figure 3). The systematic herring survey used the more precise Ichthystick II Electronic Fish Measuring Board (Northeast Fisheries Science Center, Woods Hole, MA, USA), with the board's data output format set to "Limnoterra" mode. ("Limnoterra" was the code for millimeter measurements in the Fisheries Scientific Computer System [FSCS] version 1.6.) The Ichthystick board was set to measure fish in millimeters to the nearest 0.1 mm, e.g., lengths of 9.50 and 10.49 cm recorded as 9.50 and 10.49 cm, respectively (Figure 3).

During the surveys, length values from each board were electronically recorded by the board, transmitted electronically in real time to FSCS, and then digitally recorded in the FSCS database. FSCS version 1.6 was used for the stratified-random survey from 1998 to 2011 and the systematic herring survey from 1998 to present, and version 2.0 was used for the stratified-random survey from 2011 to present. All length measurements are stored in centimeters in FSCS. Measurements from Scantrol boards are rounded to the nearest whole centimeter, e.g., a recording of 11.5 cm is rounded to 12.0 cm, while a recording of 11.0 cm remains 11.0 cm. Measurements from the Ichthystick are converted from millimeter to centimeter and then truncated to 10ths of a centimeter (0.1 centimeter), e.g., a recording of 123.7 mm is stored as 12.3 cm and 128.3 mm is stored as 12.8 cm.

Our concern was that measurements rounded up to the nearest 0.5 cm by the Scantrol boards and rounded up again to the nearest centimeter in FSCS (Figure 3) could account for the differences in mean length. For example, a measurement of 11.25 cm should be recorded by the Scantrol board as 11.5 cm and from there recorded into FSCS as 12.0 cm. This would possibly create a measurement discrepancy of up to 0.75 cm for individual measurements by the Scantrol boards. Our overall goals were to determine if this rounding created a bias in fish length measurements with the Scantrol board and if biases did occur, to what extent. The objectives of the study were twofold: 1) determine that the measurement boards and FSCS rounding algorithms were providing values as stated and 2) evaluate the accuracy of the measurements when compared against known values.

METHODS AND MATERIALS

To calibrate the electronic measuring boards, we compared calibration (i.e., known) lengths to values recorded by the measuring boards and recorded in FSCS. We conducted 2 series of measurements using 1) a set of random lengths and 2) a set of systematic lengths.

The first series of measurements used 13 wooden dowels to fit roughly into 3 length categories: 9.00 – 12.00 cm, 19.00 – 22.00 cm, and >28.00 cm. The lengths of the dowels were measured with vernier calipers to a precision of 0.01 cm (termed "known length," L_C). We connected either a Scantrol or an Ichthystick fish measurement board individually to a computer via a 9-pin RS232 serial port. Only 1 board was connected to the computer for a measurement set. Each dowel was numbered, the 13 numbers were randomized, and each dowel was measured 3 times (i.e., a measurement set) for each board. The order of each dowel was the same for each measurement set. Each measurement was recorded by the board and transmitted to the computer. Measurement values were logged with Microsoft Hyperterminal software and were corroborated with the measurements displayed on the electronic displays connected to each board.

Both board types measure lengths by placing a magnet at the location where the length is to be obtained. For standardization and consistency, the magnet was placed next to the end of each dowel. For both board types, the first 3 measurement sets were recorded with Hyperterminal software, and the second 3 sets were recorded into FSCS. At the time of these measurements, length values could not be simultaneously recorded by the board and logged to FSCS because the Hyperterminal program controlled the serial port. We compared length values among FSCS recordings, board displays, and the known values. To determine the variability within board types, measurements were repeated on 3 different Ichthystick and Scantrol boards. After the first series of measurements, we found systematic biases in 2 of the 3 Scantrol boards, so a Java program was written to simultaneously record measurements from the Scantrol board and FSCS for the series of systematic measurements.

Because of the biases observed in 2 of the 3 Scantrol boards, a second series of systematic measurements was conducted (setup shown in Figure 4). A wooden dowel was cut to 10.00 cm (verified by vernier calipers) and placed with one end at the 0 mark on each Scantrol board. A ruler with millimeter precision was affixed to the board with the 5-cm mark aligned with the dowel. The dowel was then placed with one end at 15 cm (based on the ruler, not the markings on the board) and a measurement obtained. The dowel was moved at 1-mm increments and measurements obtained until the 10-cm range (15 to 25 cm) was completed. A Java program allowed simultaneous recording of the Scantrol measurement and the length recorded in FSCS. Time stamps for each recording were used to match measurements. The first series of measurements confirmed no systematic biases in Ichthystick measurements, so only Scantrol boards were used for this series. To determine whether all Scantrol boards should be measured, we searched the FSCS database for which boards were used to measure Atlantic herring during the stratified-random survey. All Scantrol boards were used at some time during 1998 to 2012 (Table 1), so all were used in this study.

Deviations between known lengths, output measurements from Ichthystick and Scantrol boards, and length measurements recorded in FSCS were computed to investigate whether output from the fish measuring boards were consistent with stated algorithms, to determine whether length values recorded in FSCS were consistent with stated algorithms, and to evaluate the accuracy of length values recorded in FSCS. Known lengths were converted to the precision used for each stage based on the rounding algorithms used by each measuring board type and FSCS input.

RESULTS

Random Length Measurement Series

Length measurements output by the Icthystick boards were within ±0.12 cm of the known lengths, with over 97% of the values within ±0.1cm of the known lengths (Table 2; Figure 5A). The mean deviations were -0.02, -0.04, 0.00, and -0.03 cm for the ”UNK,” “IMFB009,” “IMFB008,” and “IMFB007” boards, respectively. The first set of measurements was conducted with an Ichthystick board whose serial number was not recorded, therefore we do not know if the “UNK” board is one of the other boards (IMFB009, IMFB008, or IMFB007). The measurements from the “UNK” board do not match measurements from any of the other boards, so it appears the “UNK” board was not a replicate of any of the other boards, but this cannot be confirmed.

Length measurements output by the Scantrol boards were consistent with the expected lengths based on the Scantrol algorithm of rounding to the nearest 0.5 cm in 77% of the measurements (Table 3; Figure 5B). The remaining measurements were either 0.5 cm low (negative deviation) or high (positive deviation) of the correct rounded value. The serial number of the “UNK” Scantrol board was not recorded. While the “UNK” measurements are not an exact match to any of the other boards (2090, 2092, and 2094), they are similar to board ‘2090,’ so the “UNK” and “2090” boards may be the same. The deviations were board dependent. The “UNK” and “2090” boards had all -0.5 cm deviations (i.e., all deviations were negative), “2092” had all but 1 deviations of 0.0 cm (the only deviation was 0.5 cm), and “2094” had all 0.5 cm deviations (i.e., all deviations were positive). Negative deviations occurred when the known length was in the length intervals of (x.75:x.99 cm) and (x.25:x.49 cm), where x denotes the integer cm value. Positive deviations occurred when the known length was in the length intervals of (x.00:x.24 cm) and (x.50:x.74 cm).

Length measurements recorded in FSCS from Icthystick boards were consistent with the FSCS truncation algorithm (mm measurements converted to cm and truncated to 0.1 cm) in 30 of 39 (77%) measurements (Table 4; Figure 6A). The remaining 9 measurements were within ±0.1 cm of the expected length, with 6 being 0.1 cm longer and 3 being 0.1 cm shorter than the expected length. When compared to known lengths, 36 of 39 (92%) measurements were within ±0.1 cm of known lengths, with the other measurements being within ±0.16 cm of known lengths (Figure 6B).

Length measurements recorded in FSCS from the Scantrol boards were consistent with the FSCS rounding algorithm (round to integer cm) in 36 of 39 (92%) measurements, with the remaining 3 measurements being 1 cm shorter than the expected length (Table 4; Figure 6C). These 3 measurements were all with the 20.33 cm dowel (i.e., within the x.25:x.49 cm length interval). When compared to known lengths, 3 of 39 (8%) of recorded measurements were within ±0.1 cm of known lengths, 24 of 39 (62%) of recorded measurements were within ±0.2 cm, and the remaining were within ±0.6 cm of known lengths (Figure 6D). The distribution of deviations from known lengths was skewed to positive deviations.

Measurements can be directly compared between Tables 2 and 3, but not between those tables and Table 4 because even though the L_Cs match between tables, the length values recorded in FSCS were not from the same measurement series as those from the electronic board directly. In all measurements, deviations between the measurements recorded to FSCS and the output measurements indicated that values input to FSCS were rounded (Scantrol) or truncated (Ichthystick) correctly.

Systematic Length Measurement Series

Systematic length measurements were conducted on 15 of 17 Scantrol boards, which represented all functional (as of Oct. 2014) Scantrol boards in the NEFSC Ecosystem Survey Branch's pool of Scantrol boards (Table 1). Two boards were not used as they are no longer functional (serial numbers 00-06 [FBD00100002] and 01-13 [FBD00200001]). The measurement length range was 15-30 cm at 1-mm increments for fish board serial # 2094 and 15-25 cm at 1-mm increments for all other boards. Each measurement series was done 3 times. Because of logistical issues, most boards were tested at the NEFSC, but 4 boards were tested on the NOAA Ship *Henry B. Bigelow* (HBB) (Table 1).

Deviations of length measurements recorded by the Scantrol boards to expected lengths based on the Scantrol rounding algorithm (known length rounded to the nearest 0.5 cm) are shown in Panel A, Figures 7-21. The majority of length measurements recorded by the Scantrol boards matched the expected lengths. Most boards had some lengths recorded 0.5 cm too long and/or 0.5 cm too short. However, boards 01-01, 2126, 2127, and 2130 consistently had deviations of -0.5 cm (Panel A, Figures 18-21). For most boards, the number of deviations was less than 5 per millimeter interval, but some boards (e.g., 00-07, 01-14, and 2094) had substantially more deviations, with up to 10 per millimeter interval (Panel B, Figures 7-21). All boards tended to have more deviations at the 0.2 to 0.3-mm and 0.6 to 0.8-mm intervals (Panel B, Figures 7-21); i.e., the distribution of deviations was double humped. Because of the consistency in deviations among groups of boards, hereafter boards 01-01, 2126, 2127, and 2130 will be referred to as "Type A," and all other boards will be referred to as "Type B."

Deviations of length measurements recorded by FSCS to expected lengths based on the Scantrol and FSCS rounding algorithms are shown in Panel C, Figures 7-21. The majority of length measurements recorded by FSCS matched expected lengths, with Type B boards having a mix of -1.0 and 1.0 cm deviations, and Type A boards having almost all -1.0 cm deviations.

For Type B boards, all length measurements recorded into FSCS had positive deviations (Panel D, Figures 7-21), whereas Type A boards had positive and negative deviations (Panel D, Figures 18-21). Deviations were fairly consistent over the length range 15 to 25 cm for most boards, but some boards had higher deviations at specific lengths. These patterns were not consistent among boards (e.g., board 00-01 had high deviations at 20 cm, but the 20-cm mark did not have high deviations in other boards). Mean deviations tended to be centered at 0.25 cm for Type B boards and at 0.05 cm for Type A boards (Panel D, Figures 7-21).

In all measurements, values input to FSCS were rounded correctly (data not shown). In other words, regardless of the accuracy of Scantrol rounding, FSCS appears to be implementing its rounding algorithm correctly.

DISCUSSION

Length measurements output from the Ichthystick measurement boards are consistent with the stated precision of 0.01 cm, and lengths are truncated to 0.1 cm precision correctly in FSCS. Length measurements from the Ichthystick measurement boards were consistently within 0.2 cm of known and expected lengths output from the boards and recorded in FSCS. The <2 mm deviations, i.e., difference between the measured length and the known or expected length, tended to be negatively skewed, suggesting an offset in the Ichthystick calibration. The Ichthystick measuring boards have a calibration routine that is run prior to all surveys, and each

board was calibrated prior to the measurements conducted for this study. The calibration routine has the human operator place the magnet at 8 locations from 10 to 80 cm in 10 cm increments, and then at 0. These calibration measurements are used to generate a regression slope and intercept for each board which is used to measure fish length. The results of this study suggest the Ichthystick calibrations are accurate to 0.1 cm. It is unclear whether the negative bias is due to the human factor of positioning the magnet at exactly the correct location or if there is a slight (<1 mm) offset in the instrumentation. Regardless, the error is an order of magnitude smaller than the centimeter precision required for the NEFSC fisheries surveys.

The expected rounding algorithm of the Scantrol boards is to round to the nearest 0.5 cm, and then FSCS rounds up to the nearest integer. Our results show that FSCS is rounding Scantrol values correctly, so all deviations are generated from the Scantrol boards. Given these rounding schemes, millimeter measurements recorded in FSCS will have 0, -0.1, -0.2, 0.7, 0.6, 0.5, 0.4., 0.3, 0.2, and 0.1 cm systematic deviations (i.e., bias) for measurements at x.0, x.1, x.2, x.3, x.4, x.5, x.6, x.7, x.8, and x.9 mm intervals (where x is an integer length), respectively. The expected mean deviation over a centimeter interval will be 0.25 cm for Type B boards, assuming uniform distribution of lengths over the centimeter interval. Most Type B boards had biases near 0.25 cm for FSCS-recorded lengths compared to known lengths (Table 1), but some Type B boards had biases of up to 0.5 cm (e.g., fish boards 00-07, 01-02, 01-14, and 2094). Type B boards with biases different than 0.25 cm may have a mechanical offset in the location of the sensor relative to the "backstop" of the board. For example, board #2094 appeared to have the most severe bias, where the Scantrol deviations were all positive and the FSCS length bias was about 0.5 cm. An offset only needs to be 1-2 mm to affect the measurements.

Type A boards appear to have a different rounding algorithm applied to the lengths (Table 1), where millimeter lengths are rounded down to the nearest 0.5 cm rather than to the nearest 0.5 cm. Millimeter measurements between x.0 and x.49 are rounded down to x.0, and measurements between x.5 and x.99 are rounded down to x.5. In this case, FSCS values will have 0, -0.1, -0.2, -0.3, -0.4, 0.5, 0.4, 0.3, 0.2, and 0.1 cm systematic deviations for measurements at x.0, x.1, x.2, x.3, x.4, x.5, x.6, x.7, x.8, and x.9 mm intervals, respectively. The expected mean deviation over a centimeter interval will be 0.05 cm, assuming uniform distribution of lengths over the centimeter interval.

Our measurements showed that mean deviations of Type A boards were centered at 0.05 cm and Type B boards were centered at 0.25 cm, supporting the assertion that 2 different rounding algorithms are being employed by Scantrol boards. Of the 4 Type A boards, 3 were used from 2009 to present, indicating they were purchased more recently than the others. Interestingly, all 4 Type A boards were tested on board the HBB. We used the same laptop and desktop computer for all measurements (i.e., we did not use different computers or cables for the measurements on the HBB) so it appears these boards are different.

To evaluate the effect of Type B biases on length frequency distributions, we applied the observed rounding algorithms to Atlantic herring lengths (n=7512) from midwater trawl catches during the systematic herring survey in the Gulf of Maine during 2012. These lengths were stored in the FSCS database with 0.1 cm precision. The length frequency distribution is multi-modal, with the largest mode centered about 22 cm, smaller modes at about 13 cm and 17 cm (Figure 22), and a mean of 21.97 cm (Table 5). For Ichthystick measurements, mean lengths output from the boards and recorded in FSCS were nearly identical to the original mean. For Scantrol boards, the simulated means (Table 5) showed an increase in mean length by about 0.25 cm, which matched the expected increase based on the rounding algorithms. For Scantrol boards

with offsets (e.g., +0.5 cm), the simulated means were similar to those whose lengths were rounded up. Interestingly, when the offset was negative, the overall mean length did not decrease. This is most likely due to the overall positive bias of rounding lengths. The length-frequency distributions were similar to the original length-frequency distribution (Figure 22).

Even though all Scantrol boards have a bias when compared to millimeter-precision measurements, this bias is almost always less than the 0.5 cm precision required by the NEFSC randomly-stratified survey and is less than the integer precision recorded in FSCS. In addition, the measurement biases are board dependent, and multiple boards were used to measure Atlantic herring (and presumably any species) lengths within a survey. Thus, the effect of any 1 board will be mitigated (i.e., diluted) when broad-scale means, e.g., seasonal or areal mean, are computed. For example, Scantrol board FBD00100003 (00-07) was used during surveys in 2001, 2003, 2004, and 2007 (Table 1) but measured Atlantic herring lengths in only 22%, 4%, 29%, and 36% of the stations, respectively. This board has one of the largest biases but, depending on the year, will have minimal influence on broad-scale means.

Given that the differences in mean lengths between midwater and bottom trawl catches of Atlantic herring are not wholly explained by instrument error and that we have quantified the potential error as being less than the observed difference, we can focus on exploring biological and sampling factors that may account for differences between surveys. The stratified-random survey uses a bottom trawl to sample fish, whereas the systematic herring survey uses a midwater trawl, and the stratified-random survey samples the Gulf of Maine and Georges Bank regions 2-4 weeks later than the systematic herring survey (Jech and Sullivan 2014). Experiments should be undertaken to investigate differences in availability (e.g., are larger herring closer to the bottom?) and catchability (e.g., mesh size and tow speed) of Atlantic herring between midwater and bottom trawls. Biological factors include growth and spawning in the elapsed time between surveys, vertical migration of juveniles and adults, and spatial migration of sample cohorts. It is also important to take human error into consideration; for example, accurate placement of the magnet on the board for every individual measurement is difficult, especially at sea.

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TABLES

Table 1. Scantrol Fishmeter measurement board serial number, Fisheries Scientific Computer System (FSCS) identification number (FSCS ID), and the number of stations for each year of the fall bottom trawl survey where each board measured Atlantic herring (*Clupea harengus*) lengths. Asterisks denote boards that are no longer in service. Measurement locations (Meas. Loc.) were at the Northeast Fisheries Science Center (NEFSC) and on board the NOAA Ship *Henry B. Bigelow* (HBB). MD is the mean deviation of the measurements recorded in FSCS to the known lengths.

Meas. Loc.	Serial Number	FSCS ID	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	MD (cm)
NEFSC	00-08	FBD00100001	28	35	7				29						0.25
	00-06*	FBD00100002	29	34					30						
NEFSC	00-07	FBD00100003	16		4	26			36						0.35
NEFSC	00-01	FBD00100004				21									0.22
NEFSC	01-00	FBD00100006					25								0.27
NEFSC	01-02	FBD00100007								44					0.30
NEFSC	2089	FBD00100008													0.31
NEFSC	2090	FBD00100009								53					0.23
NEFSC	2092	FBD00100010													0.30
NEFSC	2094	FBD00100011													0.44
	01-13*	FBD00200001			57	26	31	37							
NEFSC	01-14	FBD00200002				16		28							0.39
NEFSC	01-15	FBD00200003			23		20	26		51					0.23
HBB	01-01	FBD00100005		17											0.08
HBB	2126	FBD00100012									39	42	50	37	0.10
HBB	2127	FBD00100013									49	44	47	59	0.14
HBB	2130	FBD00100014									37	47	38	50	0.05

Table 2. Length (cm) measurements output by Ichthystick II Electronic Fish Measuring Boards. L_C is the known length, L_I is the length output by the Ichthystick board, and L_{I-C} is the difference between L_I and L_C for each board. The serial numbers of the boards are given in parentheses, and "UNK" is an unknown serial number.

L_C	L_I (UNK)	L_{I-C} (UNK)	L_I (IMFB009)	L_{I-C} (IMFB009)	L_I (IMFB008)	L_{I-C} (IMFB008)	L_I (IMFB007)	L_{I-C} (IMFB007)
28.85	28.87	0.02	28.85	0.00	28.88	0.03	28.87	0.02
20.47	20.51	0.04	20.44	-0.03	20.45	-0.02	20.46	-0.01
10.67	10.70	0.03	10.65	-0.02	10.65	-0.02	10.63	-0.04
10.82	10.80	-0.02	10.82	0.00	10.80	-0.02	10.77	-0.05
10.19	10.20	0.01	10.18	-0.01	10.19	0.00	10.15	-0.04
11.16	11.09	-0.07	11.10	-0.06	11.08	-0.08	11.04	-0.12
20.33	20.35	0.02	20.27	-0.06	20.41	0.08	20.29	-0.04
20.73	20.73	0.00	20.65	-0.08	20.77	0.04	20.72	-0.01
21.12	21.13	0.01	21.10	-0.02	21.14	0.02	21.09	-0.03
19.15	19.16	0.01	19.12	-0.03	19.18	0.03	19.09	-0.06
19.98	19.98	0.00	19.98	0.00	20.03	0.05	19.99	0.01
9.88	9.85	-0.03	9.83	-0.05	9.87	-0.01	9.85	-0.03
20.65	20.61	-0.04	20.59	-0.06	20.62	-0.03	20.59	-0.06
28.85	28.87	0.02	28.81	-0.04	28.88	0.03	28.84	-0.01
20.47	20.48	0.01	20.43	-0.04	20.47	0.00	20.41	-0.06
10.67	10.64	-0.03	10.63	-0.04	10.64	-0.03	10.60	-0.07
10.82	10.78	-0.04	10.80	-0.02	10.80	-0.02	10.81	-0.01
10.19	10.13	-0.06	10.12	-0.07	10.18	-0.01	10.18	-0.01
11.16	11.04	-0.12	11.06	-0.10	11.07	-0.09	11.09	-0.07
20.33	20.33	0.00	20.26	-0.07	20.32	-0.01	20.31	-0.02
20.73	20.70	-0.03	20.68	-0.05	20.73	0.00	20.74	0.01
21.12	21.09	-0.03	21.08	-0.04	21.10	-0.02	21.14	0.02
19.15	19.12	-0.03	19.11	-0.04	19.16	0.01	19.13	-0.02
19.98	19.96	-0.02	19.96	-0.02	19.99	0.01	20.01	0.03
9.88	9.81	-0.07	9.87	-0.01	9.82	-0.06	9.82	-0.06
20.65	20.61	-0.04	20.57	-0.08	20.60	-0.05	20.66	0.01
28.85	28.84	-0.01	28.82	-0.03	28.88	0.03	28.86	0.01

Table 2, continued. Length (cm) measurements output by Ichthystick II Electronic Fish Measuring Boards. L_C is the known length, L_I is the length output by the Ichthystick board, and L_{I-C} is the difference between L_I and L_C for each board. The serial numbers of the boards are given in parentheses, and "UNK" is an unknown serial number.

L_C	L_I (UNK)	L_{I-C} (UNK)	L_I (IMFB009)	L_{I-C} (IMFB009)	L_I (IMFB008)	L_{I-C} (IMFB008)	L_I (IMFB007)	L_{I-C} (IMFB007)
20.47	20.44	-0.03	20.43	-0.04	20.46	-0.01	20.48	0.01
10.67	10.65	-0.02	10.63	-0.04	10.65	-0.02	10.63	-0.04
10.82	10.78	-0.04	10.74	-0.08	10.80	-0.02	10.75	-0.07
10.19	10.15	-0.04	10.17	-0.02	10.18	-0.01	10.12	-0.07
11.16	11.05	-0.11	11.08	-0.08	11.07	-0.09	11.08	-0.08
20.33	20.36	0.03	20.25	-0.08	20.33	0.00	20.31	-0.02
20.73	20.69	-0.04	20.70	-0.03	20.74	0.01	20.69	-0.04
21.12	21.08	-0.04	21.08	-0.04	21.18	0.06	21.09	-0.03
19.15	19.14	-0.01	19.09	-0.06	19.19	0.04	19.07	-0.08
19.98	19.96	-0.02	19.99	0.01	20.02	0.04	19.96	-0.02
9.88	9.83	-0.05	9.83	-0.05	9.87	-0.01	9.83	-0.05
20.65	20.60	-0.05	20.61	-0.04	20.67	0.02	20.61	-0.04

Table 3. Length (cm) measurements output by Scantrol FishMeter measurement boards. L_C is the known length, L_{C_SA} is the known length rounded to the nearest 0.5 cm (i.e., Scantrol rounding algorithm), L_S is the length output by the Scantrol board, L_{S-C} is the difference between L_S, and L_C, L_{S-C_SA} is the difference between L_S and L_{C_SR} for each board. The serial numbers of the boards are given in parentheses, and "UNK" is an unknown serial number.

L_C	L_{C_SA}	L_S (UNK)	L_{S-C} (UNK)	L_{S-C_SA} (UNK)	L_S (2090)	L_{S-C} (2090)	L_{S-C_SA} (2090)	L_S (2092)	L_{S-C} (2092)	L_{S-C_SA} (2092)	L_S (2094)	L_{S-C} (2094)	L_{S-C_SA} (2094)
28.85	29.0	28.5	-0.35	-0.5	28.5	-0.35	-0.5	29.0	0.15	0.0	29.0	0.15	0.0
20.47	20.5	20.5	0.03	0.0	20.5	0.03	0.0	20.5	0.03	0.0	20.5	0.03	0.0
10.67	10.5	10.5	-0.17	0.0	10.5	-0.17	0.0	10.5	-0.17	0.0	11.0	0.33	0.5
10.82	11.0	11.0	0.18	0.0	10.5	-0.32	-0.5	11.0	0.18	0.0	11.0	0.18	0.0
10.19	10.0	10.0	-0.19	0.0	10.0	-0.19	0.0	10.5	0.31	0.5	10.5	0.31	0.5
11.16	11.0	11.0	-0.16	0.0	11.0	-0.16	0.0	11.0	-0.16	0.0	11.0	-0.16	0.0
20.33	20.5	20.5	0.17	0.0	20.0	-0.33	-0.5	20.5	0.17	0.0	20.5	0.17	0.0
20.73	20.5	20.5	-0.23	0.0	20.5	-0.23	0.0	20.5	-0.23	0.0	21.0	0.27	0.5
21.12	21.0	21.0	-0.12	0.0	21.0	-0.12	0.0	21.0	-0.12	0.0	21.0	-0.12	0.0
19.15	19.0	19.0	-0.15	0.0	19.0	-0.15	0.0	19.0	-0.15	0.0	19.0	-0.15	0.0
19.98	20.0	20.0	0.02	0.0	20.0	0.02	0.0	20.0	0.02	0.0	20.0	0.02	0.0
9.88	10.0	9.5	-0.38	-0.5	9.5	-0.38	-0.5	10.0	0.12	0.0	10.0	0.12	0.0
20.65	20.5	20.5	-0.15	0.0	20.5	-0.15	0.0	20.5	-0.15	0.0	20.5	-0.15	0.0
28.85	29.0	28.5	-0.35	-0.5	28.5	-0.35	-0.5	29.0	0.15	0.0	29.0	0.15	0.0
20.47	20.5	20.5	0.03	0.0	20.5	0.03	0.0	20.5	0.03	0.0	20.5	0.03	0.0
10.67	10.5	10.5	-0.17	0.0	10.5	-0.17	0.0	10.5	-0.17	0.0	11.0	0.33	0.5
10.82	11.0	10.5	-0.32	-0.5	10.5	-0.32	-0.5	11.0	0.18	0.0	11.0	0.18	0.0
10.19	10.0	10.0	-0.19	0.0	10.0	-0.19	0.0	10.0	-0.19	0.0	10.5	0.31	0.5
11.16	11.0	11.0	-0.16	0.0	11.0	-0.16	0.0	11.0	-0.16	0.0	11.0	-0.16	0.0
20.33	20.5	20.0	-0.33	-0.5	20.0	-0.33	-0.5	20.5	0.17	0.0	20.5	0.17	0.0
20.73	20.5	20.5	-0.23	0.0	20.5	-0.23	0.0	20.5	-0.23	0.0	21.0	0.27	0.5
21.12	21.0	21.0	-0.12	0.0	21.0	-0.12	0.0	21.0	-0.12	0.0	21.5	0.38	0.5
19.15	19.0	19.0	-0.15	0.0	19.0	-0.15	0.0	19.0	-0.15	0.0	19.0	-0.15	0.0
19.98	20.0	20.0	0.02	0.0	20.0	0.02	0.0	20.0	0.02	0.0	20.0	0.02	0.0
9.88	10.0	9.5	-0.38	-0.5	9.5	-0.38	-0.5	10.0	0.12	0.0	10.0	0.12	0.0
20.65	20.5	20.5	-0.15	0.0	20.5	-0.15	0.0	20.5	-0.15	0.0	21.0	0.35	0.5

Table 3, continued. Length (cm) measurements output by Scantrol FishMeter measurement boards. L_C is the known length, L_{C_SA} is the known length rounded to the nearest 0.5 cm (i.e., Scantrol rounding algorithm), L_S is the length output by the Scantrol board, L_{S-C} is the difference between L_S, and L_C, L_{S-C_SA} is the difference between L_S and L_{C_SR} for each board. The serial numbers of the boards are given in parentheses, and "UNK" is an unknown serial number.

L_C	L_{C_SA}	L_S (UNK)	L_{S-C} (UNK)	L_{S-C_SA} (UNK)	L_S (2090)	L_{S-C} (2090)	L_{S-C_SA} (2090)	L_S (2092)	L_{S-C} (2092)	L_{S-C_SA} (2092)	L_S (2094)	L_{S-C} (2094)	L_{S-C_SA} (2094)
28.85	29.0	28.5	-0.35	-0.5	28.5	-0.35	-0.5	29.0	0.15	0.0	29.0	0.15	0.0
20.47	20.5	20.5	0.03	0.0	20.5	0.03	0.0	20.5	0.03	0.0	20.5	0.03	0.0
10.67	10.5	10.5	-0.17	0.0	10.5	-0.17	0.0	10.5	-0.17	0.0	11.0	0.33	0.5
10.82	11.0	10.5	-0.32	-0.5	10.5	-0.32	-0.5	11.0	0.18	0.0	11.0	0.18	0.0
10.19	10.0	10.0	-0.19	0.0	10.0	-0.19	0.0	10.0	-0.19	0.0	10.5	0.31	0.5
11.16	11.0	11.0	-0.16	0.0	11.0	-0.16	0.0	11.0	-0.16	0.0	11.0	-0.16	0.0
20.33	20.5	20.0	-0.33	-0.5	20.0	-0.33	-0.5	20.5	0.17	0.0	20.5	0.17	0.0
20.73	20.5	20.5	-0.23	0.0	20.5	-0.23	0.0	20.5	-0.23	0.0	21.0	0.27	0.5
21.12	21.0	21.0	-0.12	0.0	21.0	-0.12	0.0	21.0	-0.12	0.0	21.0	-0.12	0.0
19.15	19.0	19.0	-0.15	0.0	19.0	-0.15	0.0	19.0	-0.15	0.0	19.5	0.35	0.5
19.98	20.0	20.0	0.02	0.0	20.0	0.02	0.0	20.0	0.02	0.0	20.0	0.02	0.0
9.88	10.0	9.5	-0.38	-0.5	9.5	-0.38	-0.5	10.0	0.12	0.0	10.0	0.12	0.0
20.65	20.5	20.5	-0.15	0.0	20.5	-0.15	0.0	20.5	-0.15	0.0	21.0	0.35	0.5

Table 4. Length measurements (cm) recorded by the Fisheries Scientific Computer System (FSCS) from an Ichthystick II Electronic Fish Measuring Board (L_{I_FSCS}) and a Scantrol FishMeter measurement board (L_{S_FSCS}). These measurements are from the boards with unknown serial numbers ("UNK" in Tables 1 and 2). L_C is the known length, L_{CI_FSCS} is the expected length in FSCS based on the Ichthystick and FSCS truncation algorithms, $L_{I\text{-}CI\_FSCS}$ is the difference between L_I and L_{CI_FSCS}, L_{I_C} is the difference between L_I and L_C, L_{CSA_FSCS} is the expected length in FSCS based on the Scantrol and FSCS rounding algorithms, $L_{S\text{-}CSA\_FSCS}$ is the difference between L_{S_FSCS} and L_{CSA_FSCS}, and L_{S_C} is the difference between L_S and L_C.

L_C	$L_{CI\ FSCS}$	L_{I_FSCS} (UNK)	$L_{I\text{-}CI\_FSCS}$ (UNK)	$L_{I\text{-}C}$ (UNK)	$L_{CSA\ FSCS}$	L_{S_FSCS} (UNK)	$L_{S\text{-}CSA\_FSCS}$ (UNK)	$L_{S\text{-}C}$ (UNK)
28.85	28.8	28.8	0.0	-0.05	29.0	29.0	0.0	0.15
20.47	20.4	20.5	0.1	0.03	21.0	21.0	0.0	0.53
10.67	10.6	10.7	0.1	0.03	11.0	11.0	0.0	0.33
10.82	10.8	10.8	0.0	-0.02	11.0	11.0	0.0	0.18
10.19	10.1	10.2	0.1	0.01	10.0	10.0	0.0	-0.19
11.16	11.1	11.1	0.0	-0.06	11.0	11.0	0.0	-0.16
20.33	20.3	20.3	0.0	-0.03	21.0	20.0	-1.0	-0.33
20.73	20.7	20.7	0.0	-0.03	21.0	21.0	0.0	0.27
21.12	21.1	21.1	0.0	-0.02	21.0	21.0	0.0	-0.12
19.15	19.1	19.1	0.0	-0.05	19.0	19.0	0.0	-0.15
19.98	19.9	19.9	0.0	-0.08	20.0	20.0	0.0	0.02
9.88	9.8	9.8	0.0	-0.08	10.0	10.0	0.0	0.12
20.65	20.6	20.6	0.0	-0.05	21.0	21.0	0.0	0.35
28.85	28.8	28.9	0.1	0.05	29.0	29.0	0.0	0.15
20.47	20.4	20.4	0.0	-0.07	21.0	21.0	0.0	0.53
10.67	10.6	10.6	0.0	-0.07	11.0	11.0	0.0	0.33
10.82	10.8	10.7	-0.1	-0.12	11.0	11.0	0.0	0.18
10.19	10.1	10.1	0.0	-0.09	10.0	10.0	0.0	-0.19
11.16	11.1	11.0	-0.1	-0.16	11.0	11.0	0.0	-0.16
20.33	20.3	20.3	0.0	-0.03	21.0	20.0	-1.0	-0.33
20.73	20.7	20.7	0.0	-0.03	21.0	21.0	0.0	0.27
21.12	21.1	21.1	0.0	-0.02	21.0	21.0	0.0	-0.12
19.15	19.1	19.1	0.0	-0.05	19.0	19.0	0.0	-0.15
19.98	19.9	20.0	0.1	0.02	20.0	20.0	0.0	0.02

Table 4, continued. Length measurements (cm) recorded by the Fisheries Scientific Computer System (FSCS) from an Ichthystick II Electronic Fish Measuring Board (L_{I_FSCS}) and a Scantrol FishMeter measurement board (L_{S_FSCS}). These measurements are from the boards with unknown serial numbers ("UNK" in Tables 1 and 2). L_C is the known length, L_{CI_FSCS} is the expected length in FSCS based on the Ichthystick and FSCS truncation algorithms, $L_{I\text{-}CI\_FSCS}$ is the difference between L_I and L_{CI_FSCS}, L_{I_C} is the difference between L_I and L_C, L_{CSA_FSCS} is the expected length in FSCS based on the Scantrol and FSCS rounding algorithms, $L_{S\text{-}CSA\_FSCS}$ is the difference between L_{S_FSCS} and L_{CSA_FSCS}, and L_{S_C} is the difference between L_S and L_C.

L_C	$L_{CI\ FSCS}$	L_{I_FSCS} (UNK)	$L_{I\text{-}CI\_FSCS}$ (UNK)	$L_{I\text{-}C}$ (UNK)	$L_{CSA\ FSCS}$	L_{S_FSCS} (UNK)	$L_{S\text{-}CSA\_FSCS}$ (UNK)	$L_{S\text{-}C}$ (UNK)
9.88	9.8	9.8	0.0	-0.08	10.0	10.0	0.0	0.12
20.65	20.6	20.6	0.0	-0.05	21.0	21.0	0.0	0.35
28.85	28.8	28.9	0.1	0.05	29.0	29.0	0.0	0.15
20.47	20.4	20.4	0.0	-0.07	21.0	21.0	0.0	0.53
10.67	10.6	10.6	0.0	-0.07	11.0	11.0	0.0	0.33
10.82	10.8	10.8	0.0	-0.02	11.0	11.0	0.0	0.18
10.19	10.1	10.1	0.0	-0.09	10.0	10.0	0.0	-0.19
11.16	11.1	11.0	-0.1	-0.16	11.0	11.0	0.0	-0.16
20.33	20.3	20.3	0.0	-0.03	21.0	20.0	-1.0	-0.33
20.73	20.7	20.7	0.0	-0.03	21.0	21.0	0.0	0.27
21.12	21.1	21.1	0.0	-0.02	21.0	21.0	0.0	-0.12
19.15	19.1	19.1	0.0	-0.05	19.0	19.0	0.0	-0.15
19.98	19.9	19.9	0.0	-0.08	20.0	20.0	0.0	0.02
9.88	9.8	9.8	0.0	-0.08	10.0	10.0	0.0	0.12
20.65	20.6	20.6	0.0	-0.05	21.0	21.0	0.0	0.35

Table 5. Mean lengths (cm) from Atlantic herring (*Clupea harengus*) captured in midwater trawls during the 2012 systematic herring survey (n=7512) derived from the original lengths, measurement board output (Ichthystick II Electronic Fish Measuring Board and Scantrol FIshMeter measurement board), and recorded in the Fisheries Scientific Computer System (FSCS). "Original lengths" is the mean length from the original length data, which were stored in FSCS in 0.1 cm precision. "Board Output" is the mean of the output from each measurement board. "FSCS" is the mean of the lengths recorded in FSCS. Ichthystick board output was rounded to 0.1-cm precision, and Ichthystick lengths in FSCS were truncated to 0.1-cm precision. Scantrol board output was rounded to the nearest 0.5 cm. The "0.5-cm bias" means were calculated by rounding to the nearest 0.5 cm and adding 0.5 cm to measurements in the length intervals L.00:L.24 and L.50:L.74, and then rounding to the nearest whole integer as recorded in FSCS. The "0.5-cm bias" means were calculated by rounding to the nearest 0.5 cm, adding -0.5 cm to measurements in the length intervals L.00:L.24 and L.50:L.74, and then rounding to the nearest whole integer as recorded in FSCS.

	Ichthystick	Scantrol	Scantrol 0.5-cm bias	Scantrol -0.5-cm bias
Original lengths	21.97	---	---	---
Board Output	21.96	21.97	22.26	21.76
FSCS	21.96	22.22	22.51	22.02

FIGURES

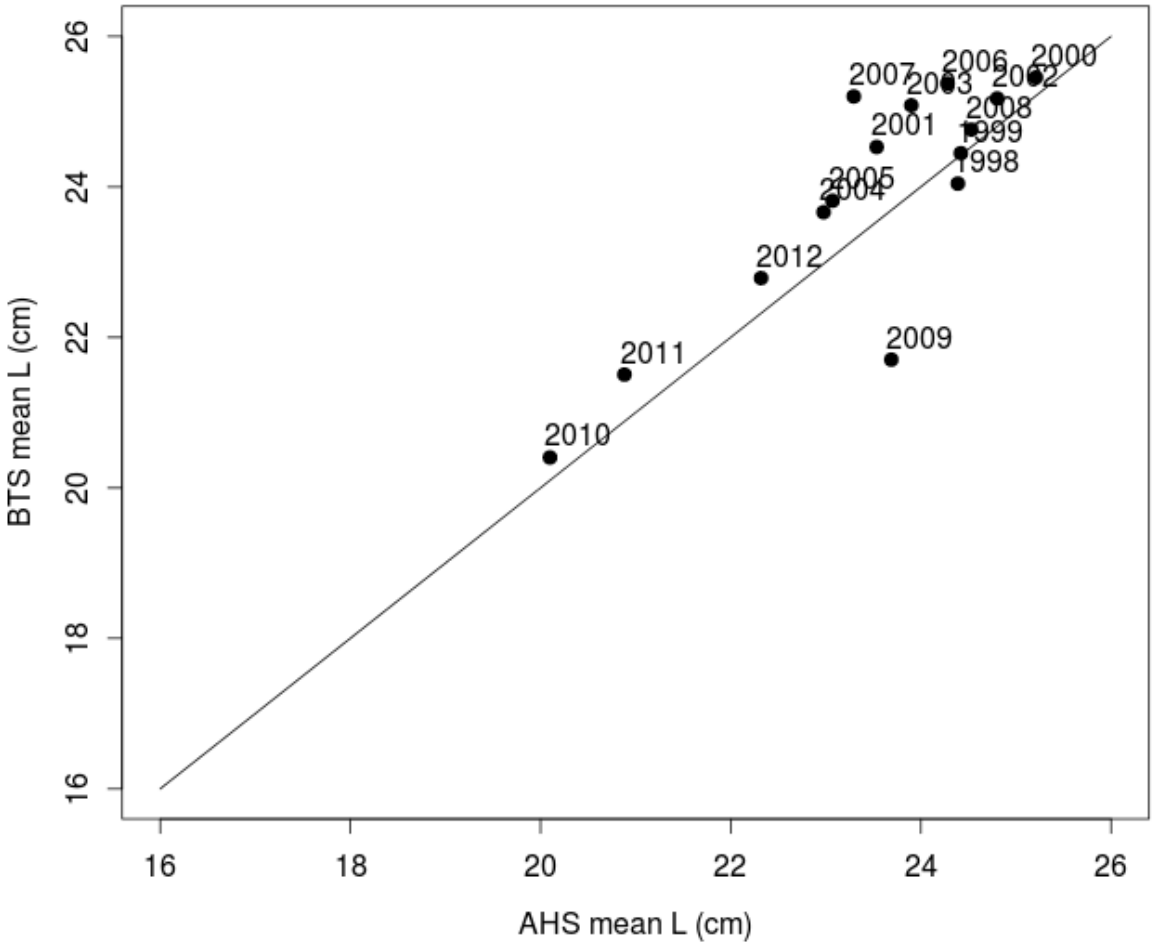

Figure 1. Atlantic herring (*Clupea harengus*) mean fork lengths from the systematic Atlantic herring survey (AHS) and from the fall stratified-random bottom trawl survey (BTS) for each year from 1998 to 2012 in the Georges Bank region.

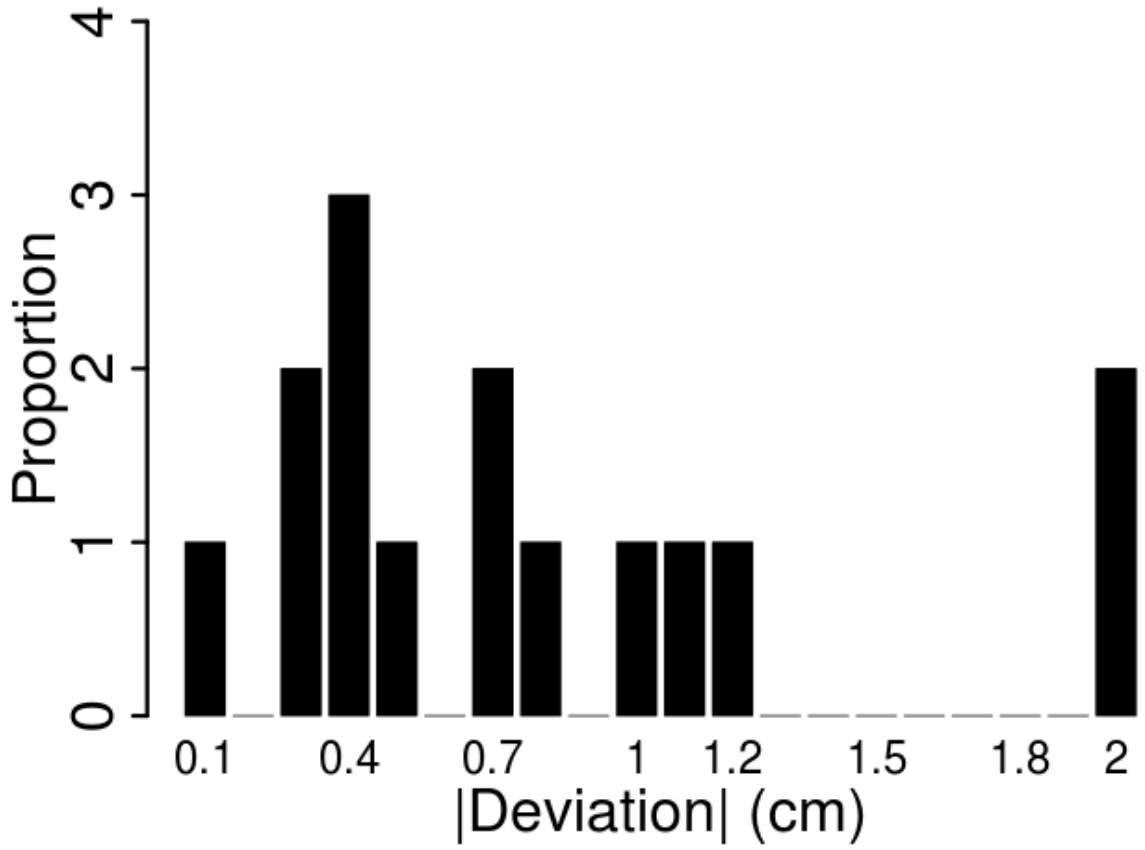

Figure 2. Frequency distribution of the magnitude of the deviations between the Atlantic herring (*Clupea harengus*) mean lengths from the systematic survey and the random-stratified survey in the Georges Bank region during 1998 to 2012.

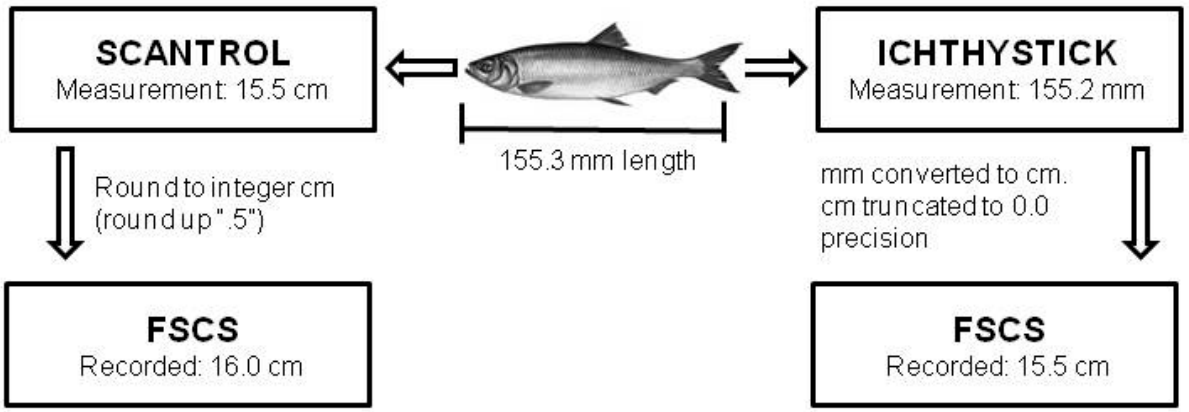

Figure 3. Schematic illustration of the fish length measurement from measurement board (Scantrol FishMeter and Icthystick II Electronic Fish Measuring Board) to the Fisheries Scientific Computer System (FSCS). The true length of an individual fish is 155.3 mm. The Icthystick records the length to tenths of a mm, whereas the Scantrol board rounds the length measurement to the nearest 0.5 cm. For Scantrol measurements, FSCS rounds length values to the nearest integer centimeter (left side of schematic). For Ichthystick measurements, the length value is converted to centimeter and truncated to a precision of 0.1 cm (right side of schematic).

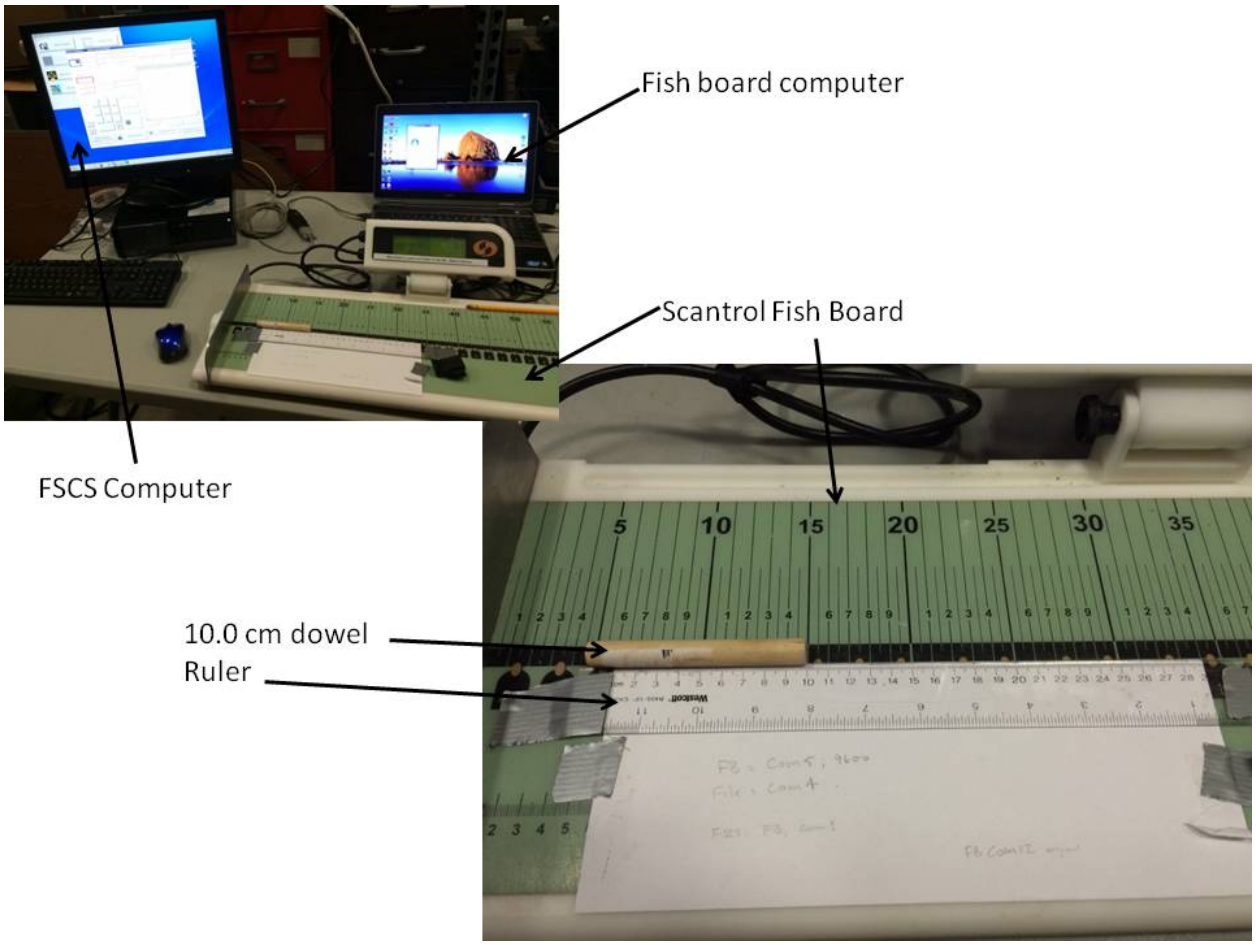

Figure 4. Measurement setup for the Scantrol FishMeter board systematic measurements.

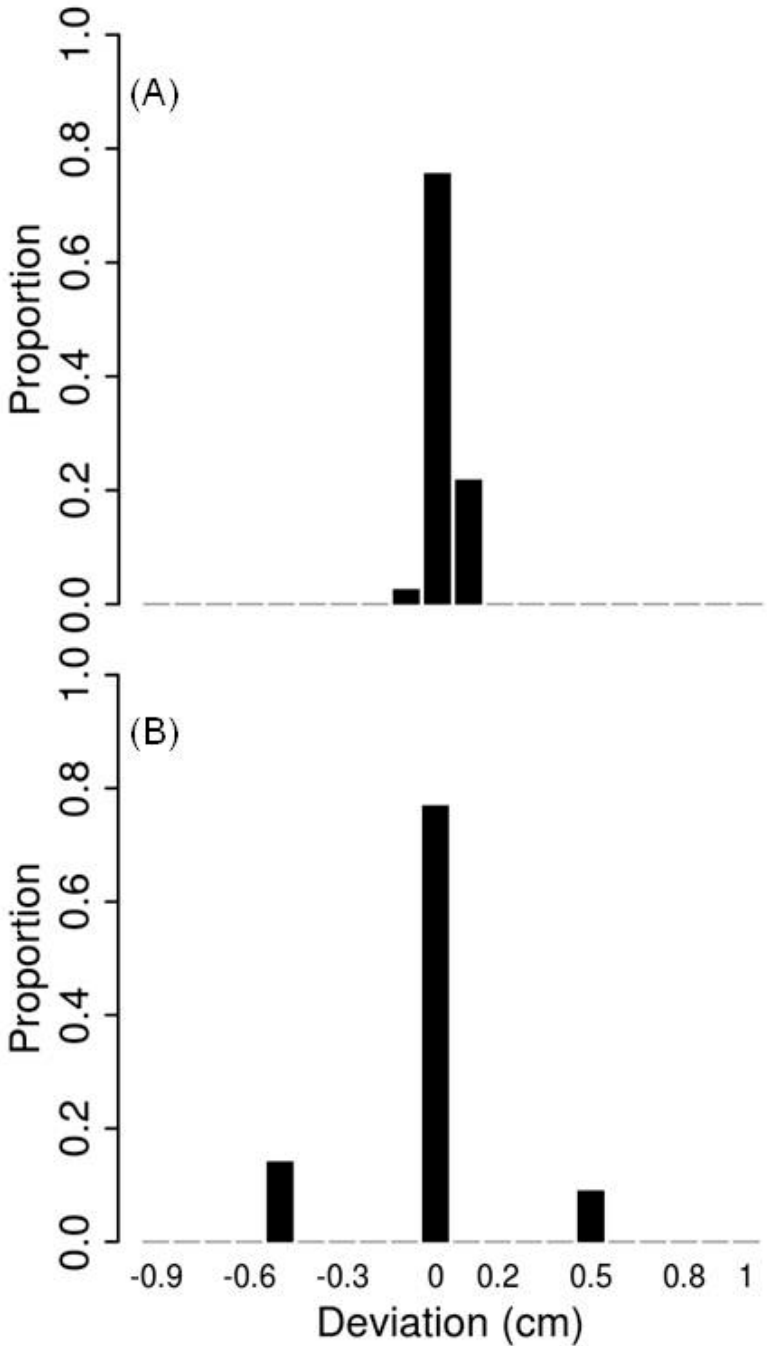

Figure 5. Panel (A): frequency distribution of the differences between the Ichthystick II Electronic Fish Measuring Board output (L_I) and the known lengths (L_C) (L_I-L_C). Panel (B): frequency distribution of the differences between the Scantrol output (L_S) and the expected output based on the Scantrol FishMeter algorithm of rounding to the nearest 0.5 cm (L_{C_SA}). The deviation labels represent the upper bound (i.e., "right" side) of each bin, where values equal to the upper bound are included in that bin. For example, the "0" bin is the proportion of values between -0.0999 and 0.0, and the "0.2" bin is the proportion of values between 0.11 and 0.2.

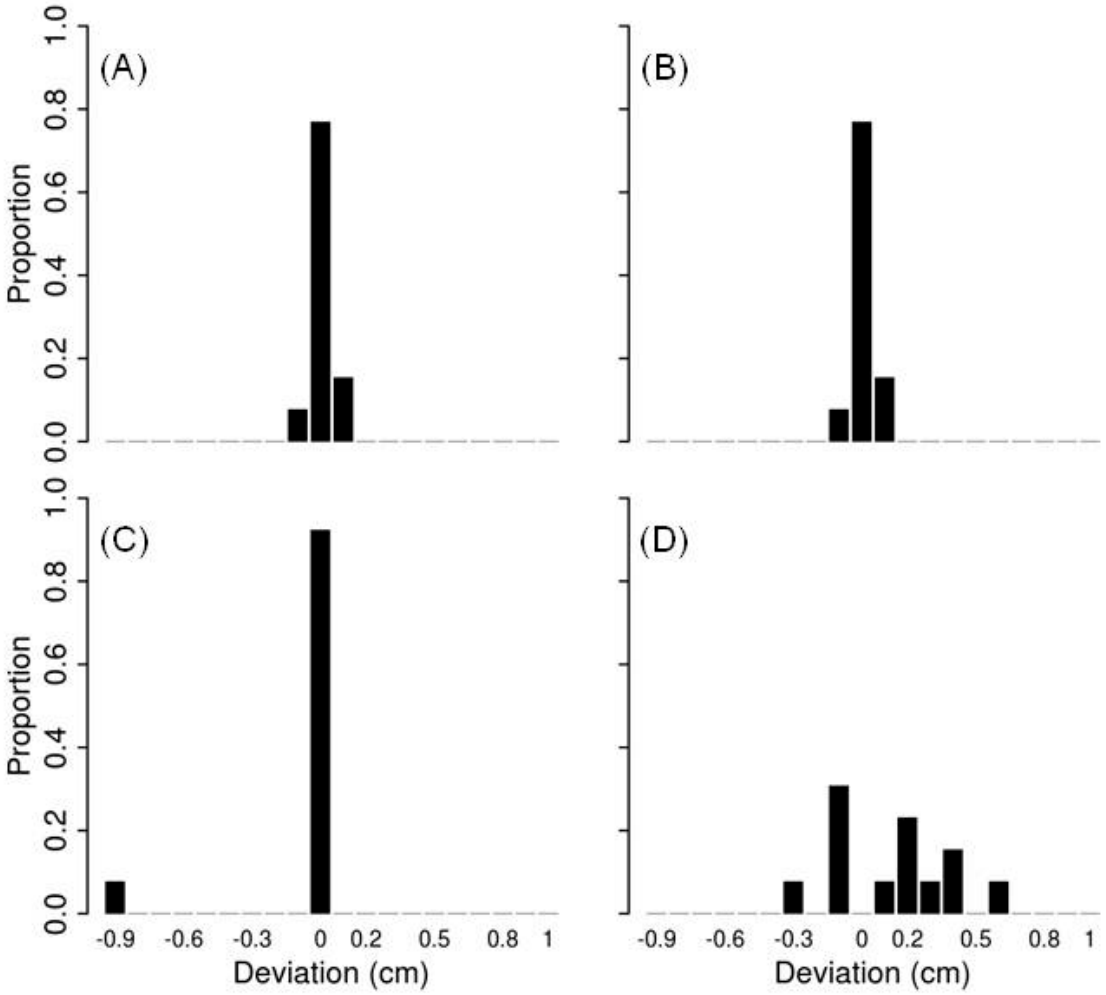

Figure 6. Panel (A): frequency distribution of the differences between Ichthystick II Electronic Fish Measuring Board length values recorded in FSCS (L_{I_FSCS}) and expected lengths based on the FSCS algorithm of converting cm to mm and truncating to 0.1 cm (L_{CI_FSCS}). Panel (B): frequency distribution of the differences between Ichthystick length values recorded in FSCS (L_{I_FSCS}) and known lengths (L_C). Panel (C): frequency distribution of the differences between Scantrol length values recorded in FSCS (L_{S_FSCS}) and expected lengths based on the FSCS algorithm of rounding to integer cm (L_{CSA_FSCS}). Panel (D): frequency distribution of the differences between Scantrol FishMeter length values recorded in FSCS (L_{S_FSCS}) and known lengths (L_C). The deviation labels represent the upper bound (i.e., 'right' side) of each bin, where values equal to the upper bound are included in that bin. For example, the '0' bin is the proportion of values between -0.099 and 0.0, and the '0.2' bin is the proportion of values between 0.101 and 0.2.

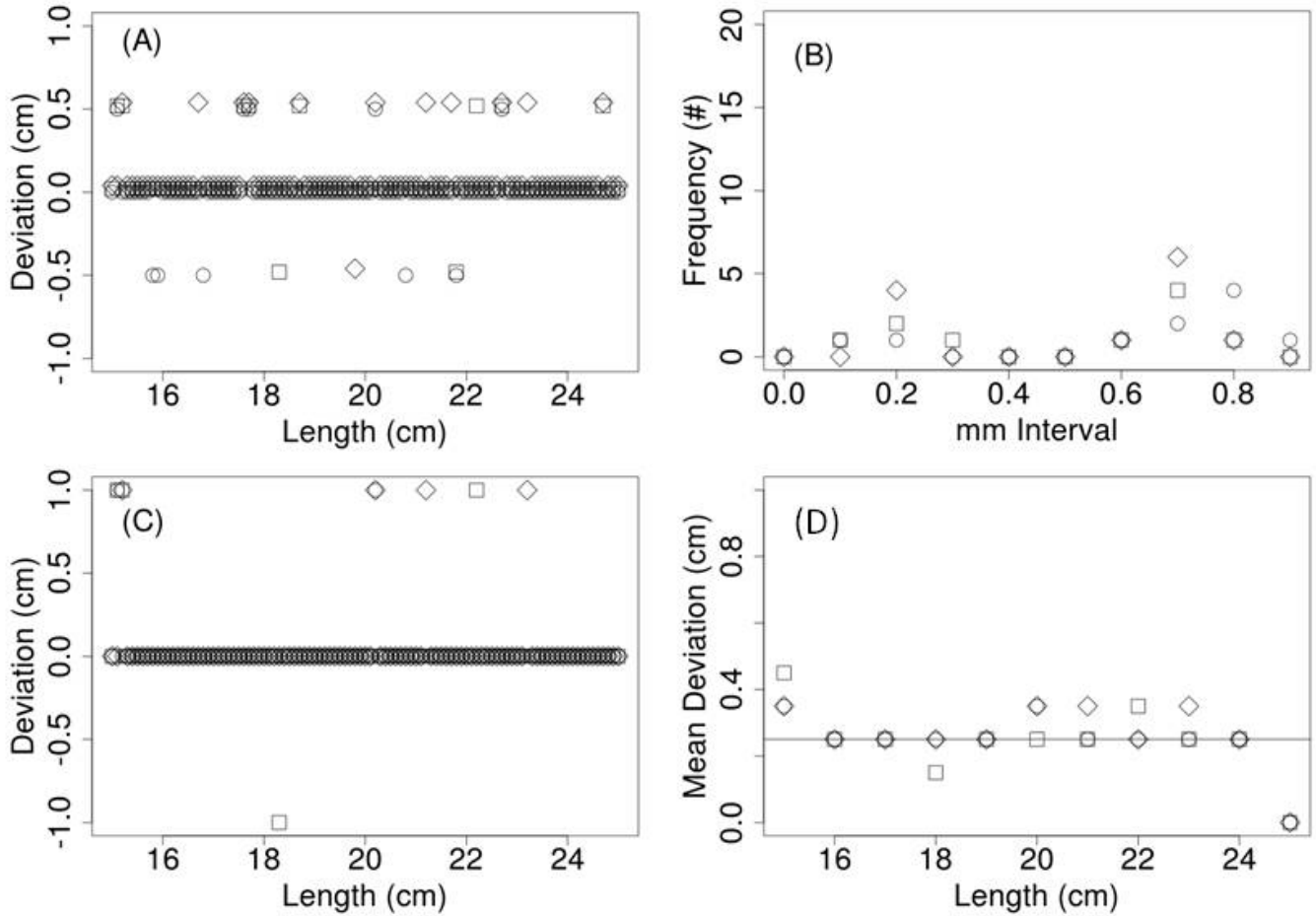

Figure 7. Fish board serial # 00-08 (FSCS equipment code: FBD00100001). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

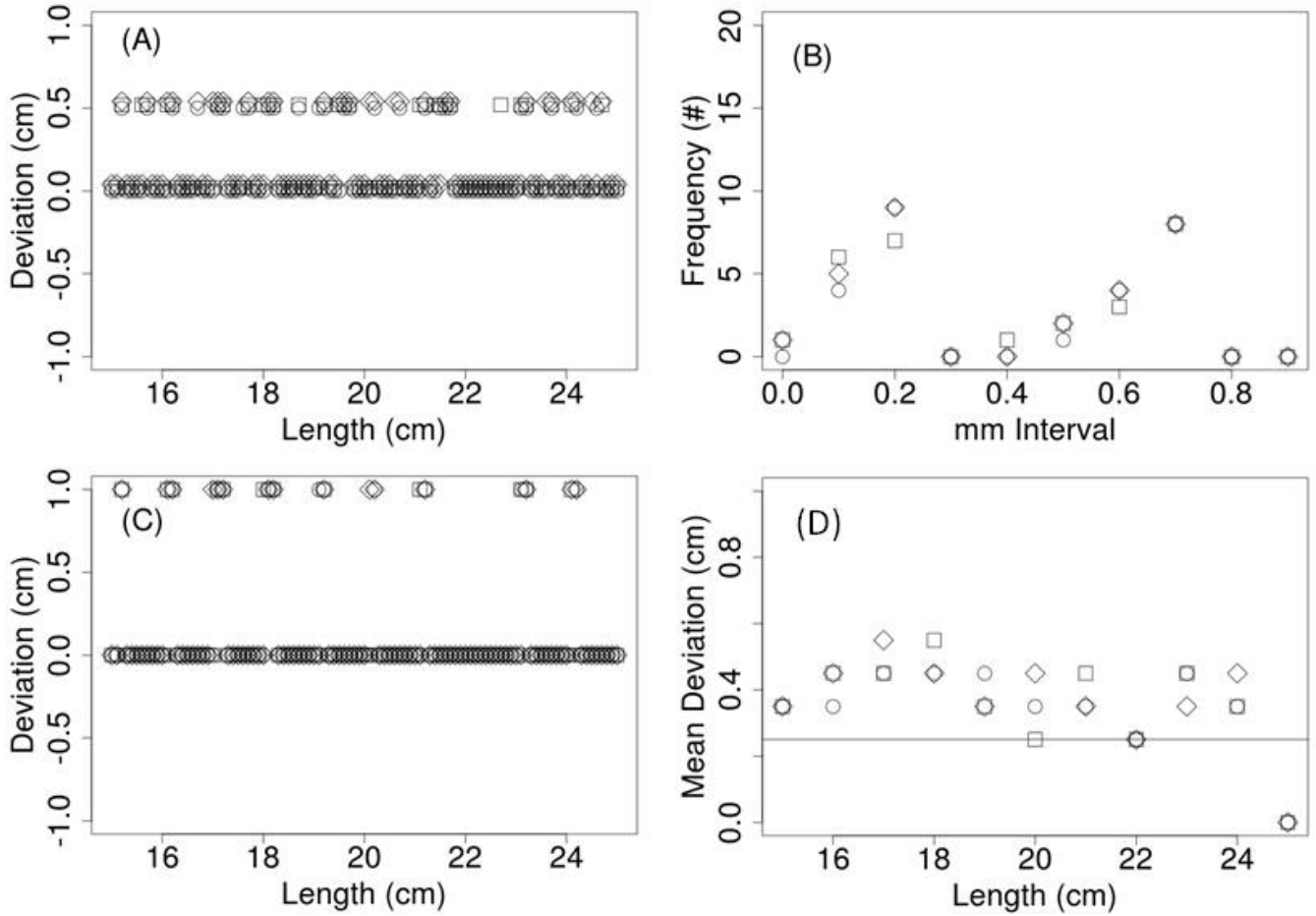

Figure 8. Fish board serial # 00-07 (FSCS equipment code: FBD00100003). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

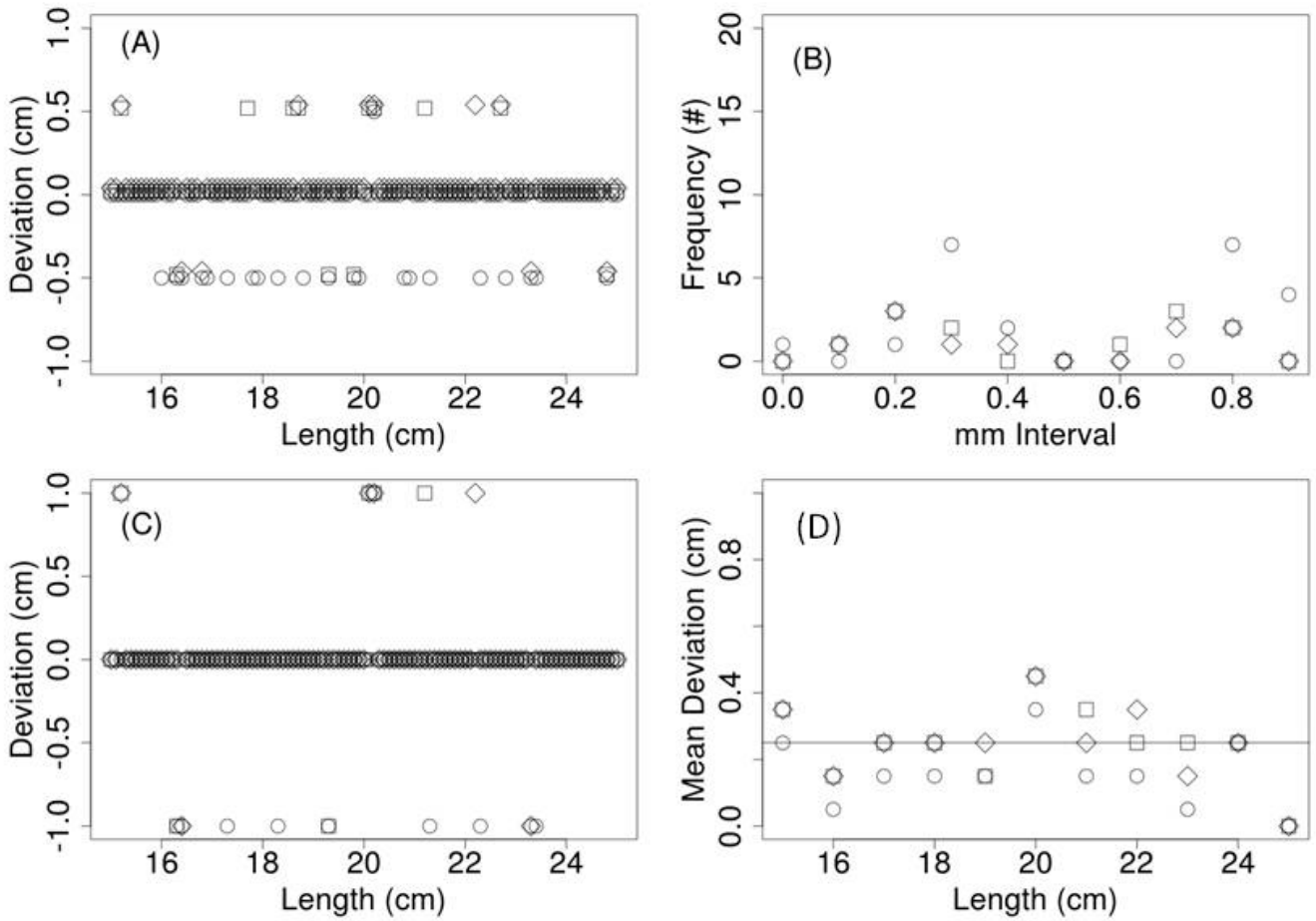

Figure 9. Fish board serial # 00-01 (FSCS equipment code: FBD00100004). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

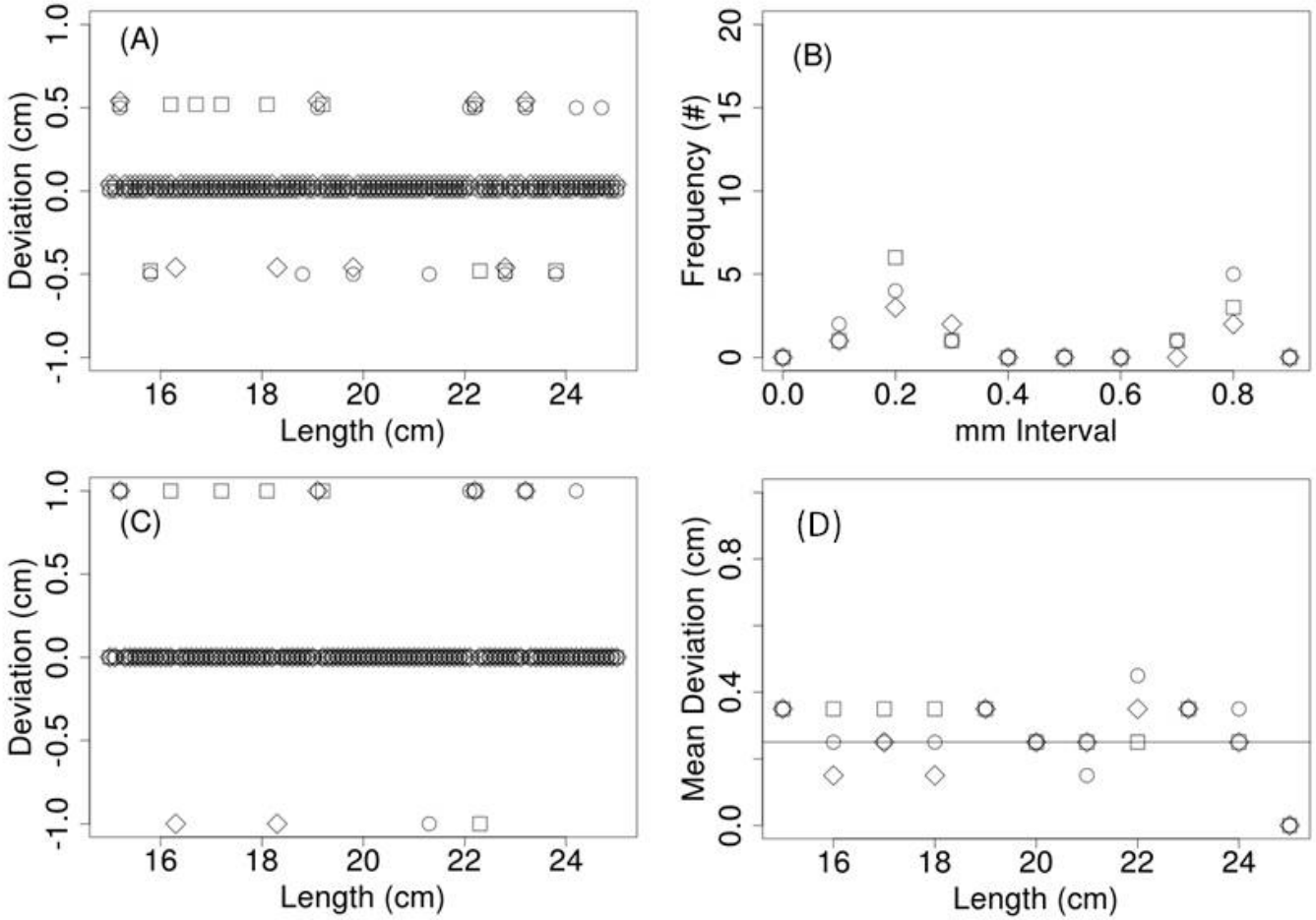

Figure 10. Fish board serial # 01-00 (FSCS equipment code: FBD00100006). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

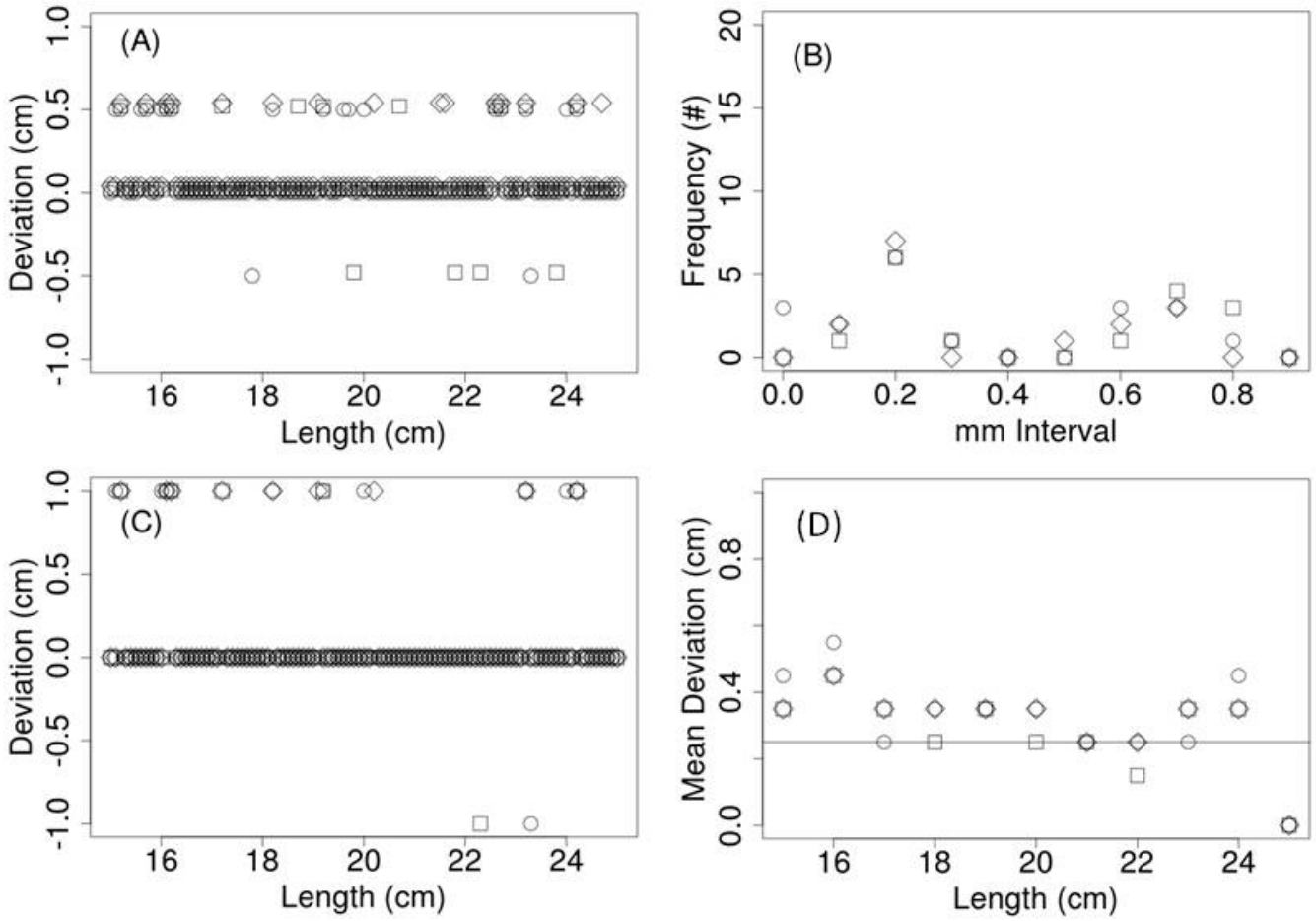

Figure 11. Fish board serial # 01-02 (FSCS equipment code: FBD00100007). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

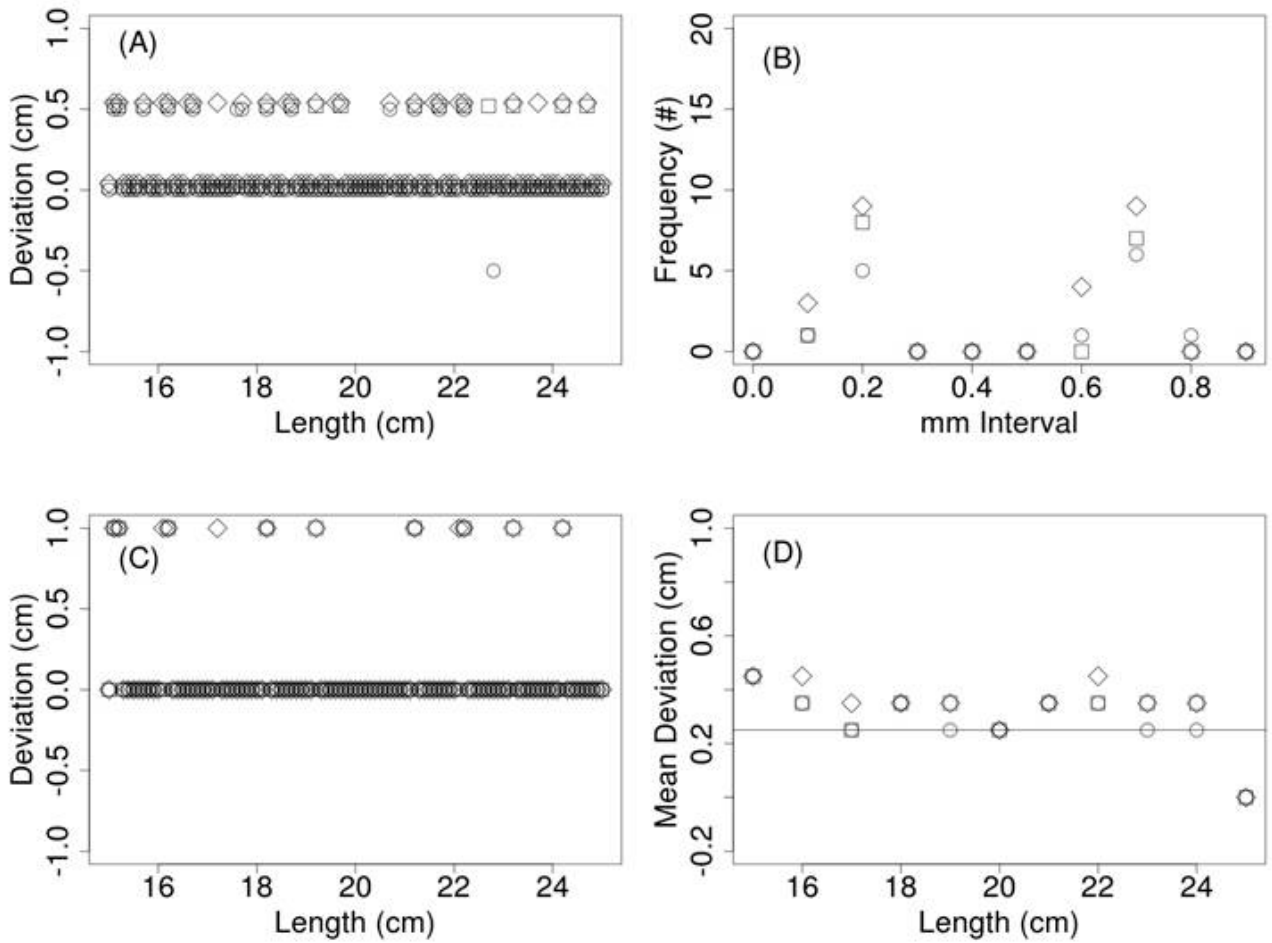

Figure 12. Fish board serial # 2089 (FSCS equipment code: FBD00100008). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

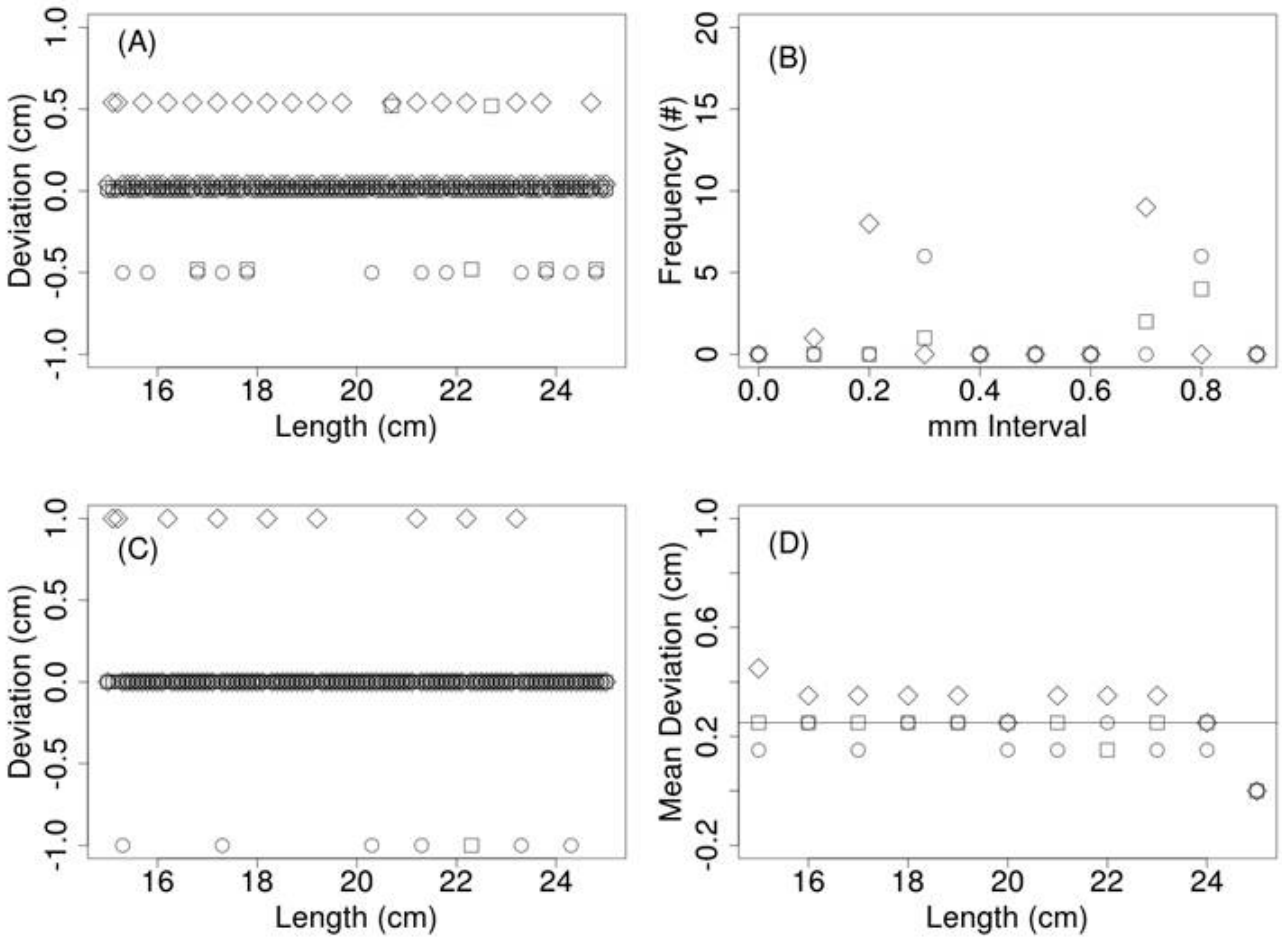

Figure 13. Fish board serial # 2090 (FSCS equipment code: FBD00100009). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

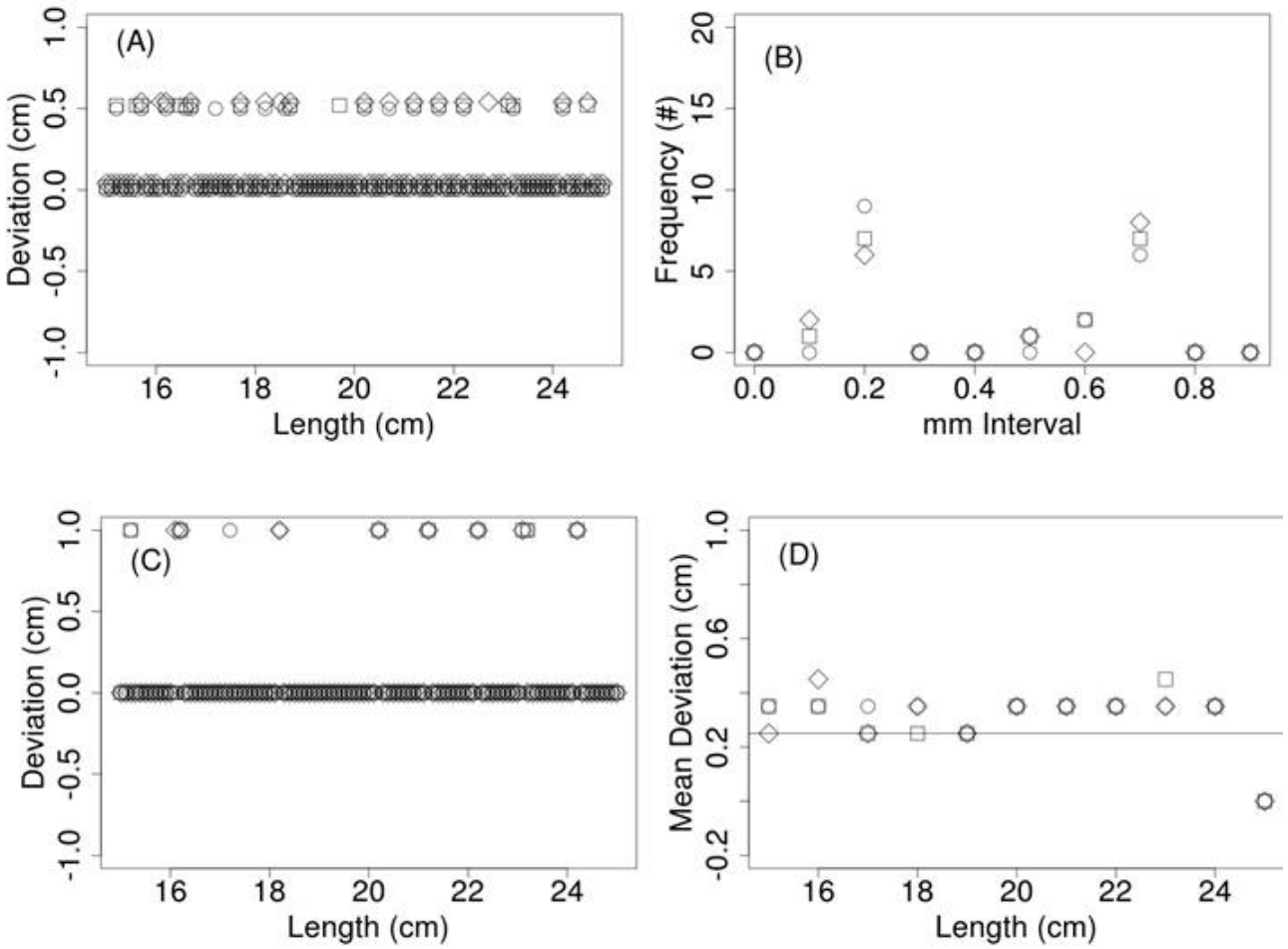

Figure 14. Fish board serial # 2092 (FSCS equipment code: FBD00100010). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

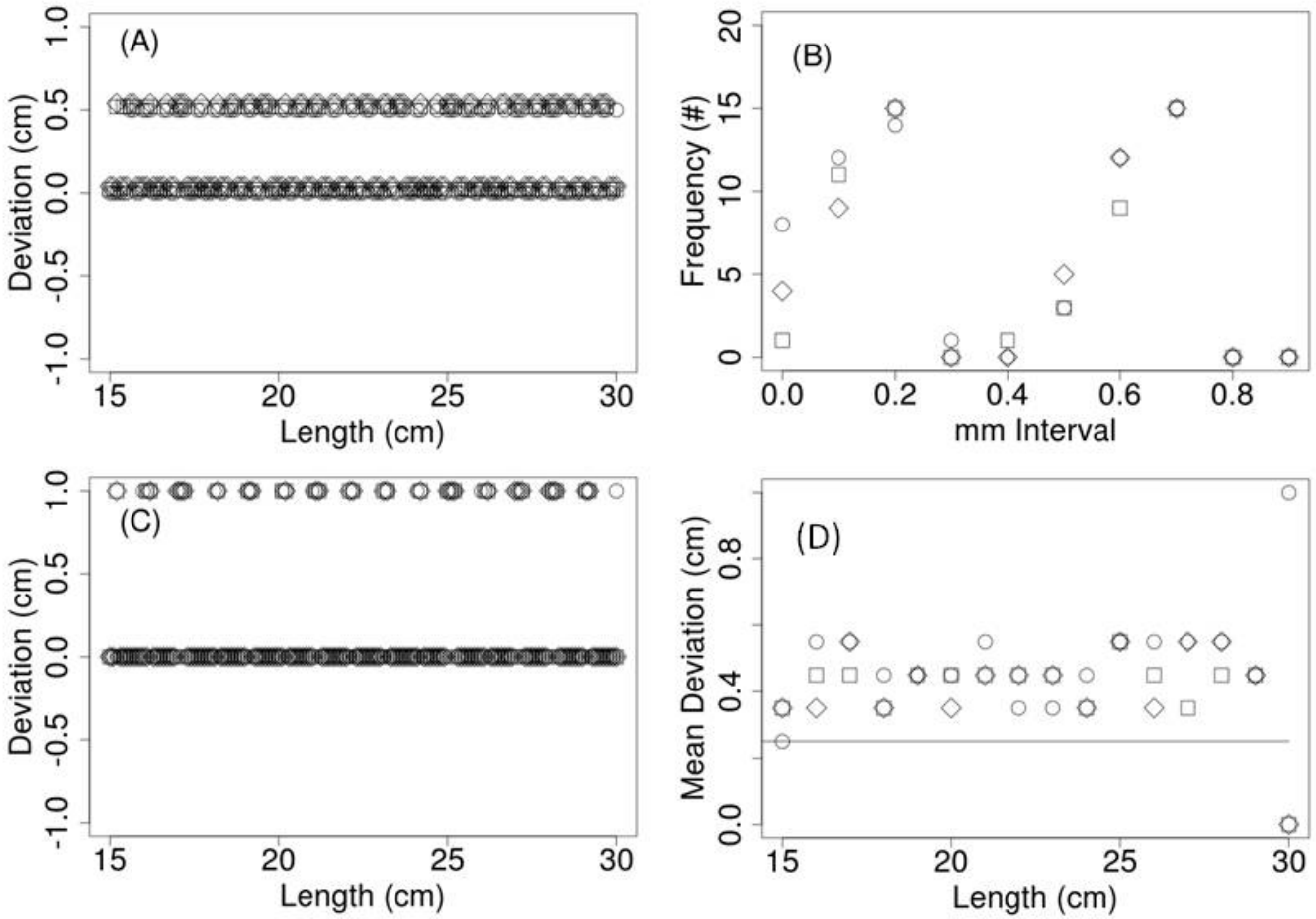

Figure 15. Fish board serial # 2094 (FSCS equipment code: FBD00100011). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

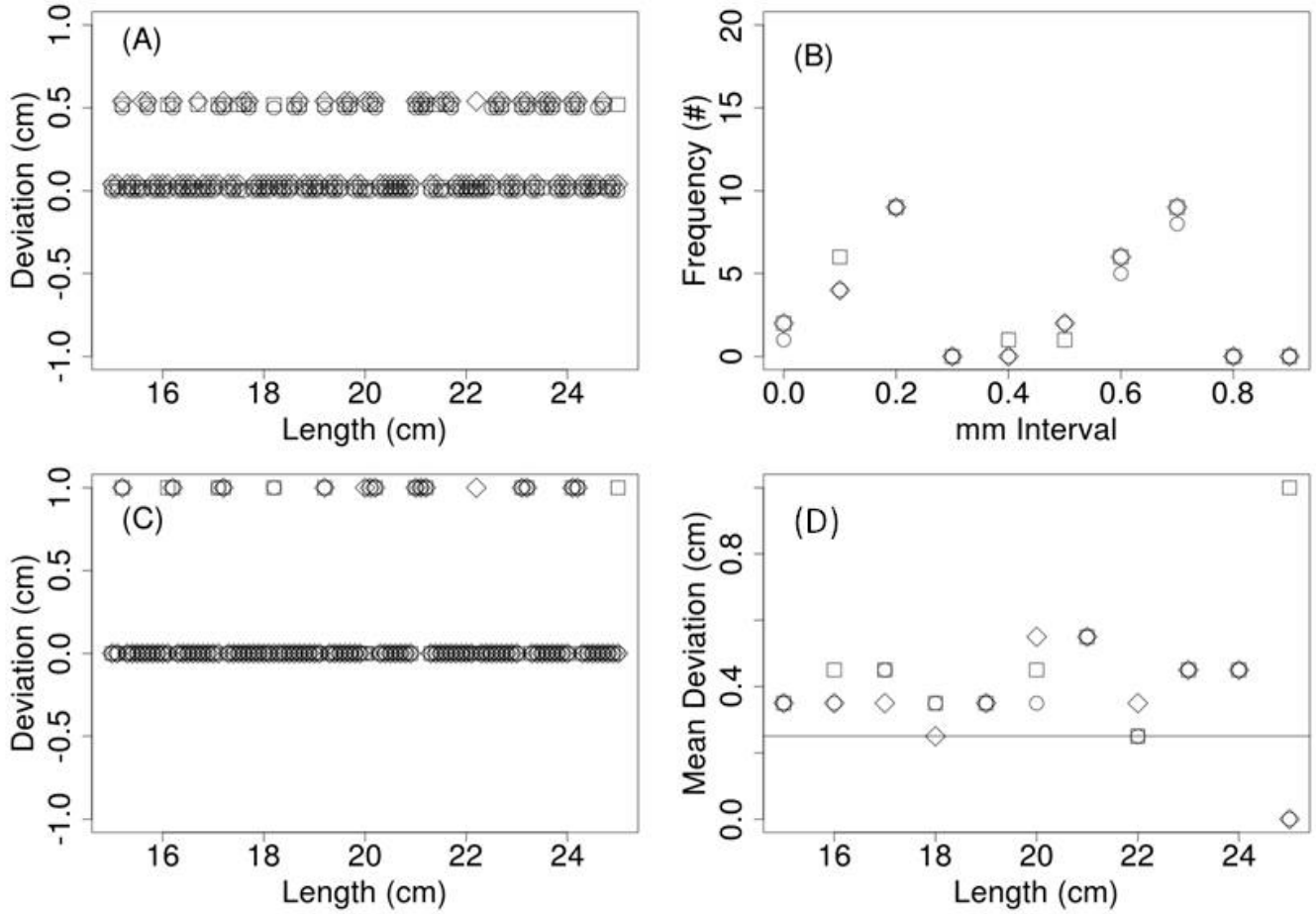

Figure 16. Fish board serial # 01-14 (FSCS equipment code: FBD00200002). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

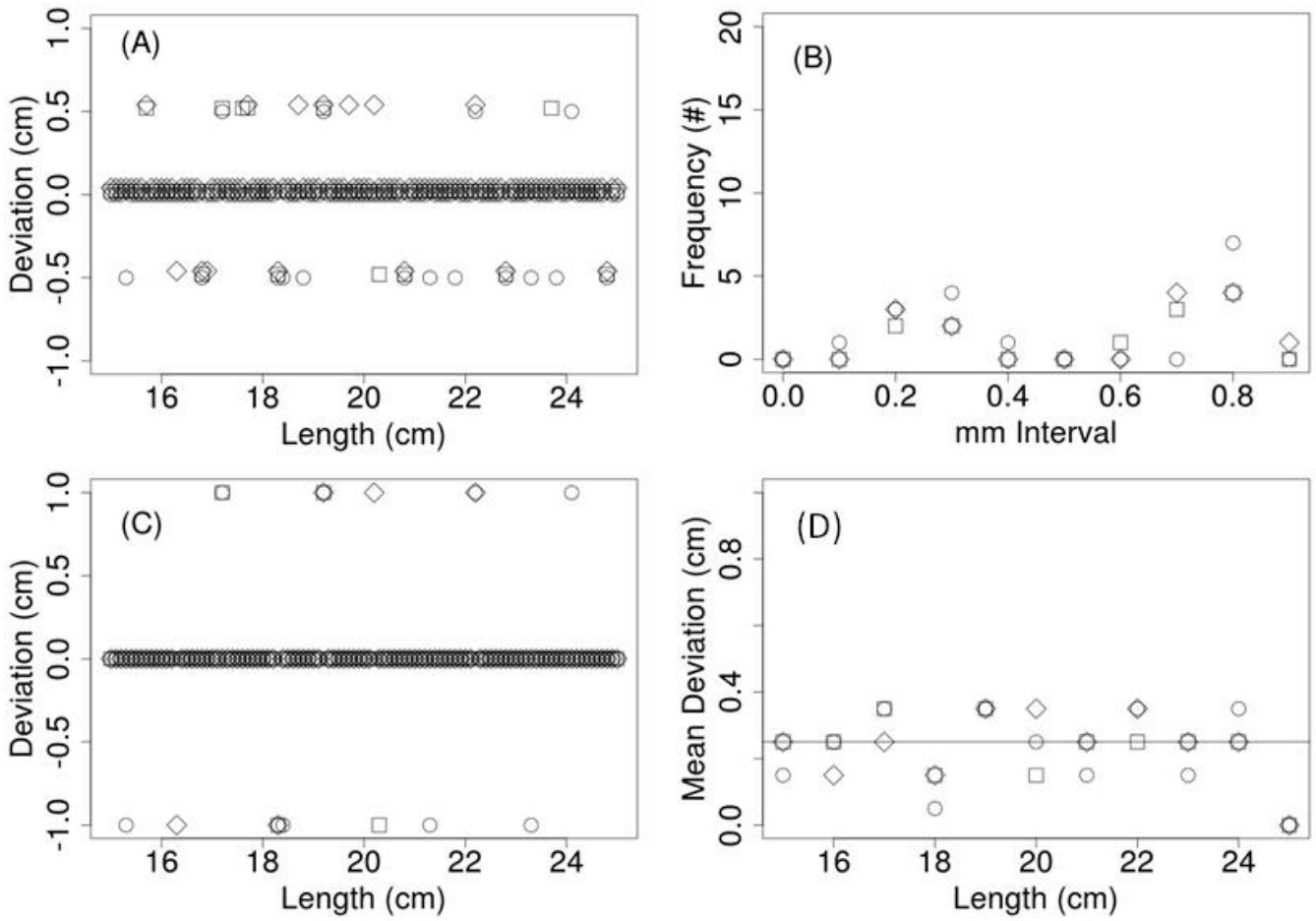

Figure 17. Fish board serial # 01-15 (FSCS equipment code: FBD00200003). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The solid line at 0.25 cm is the nominal mean deviation for Type B Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

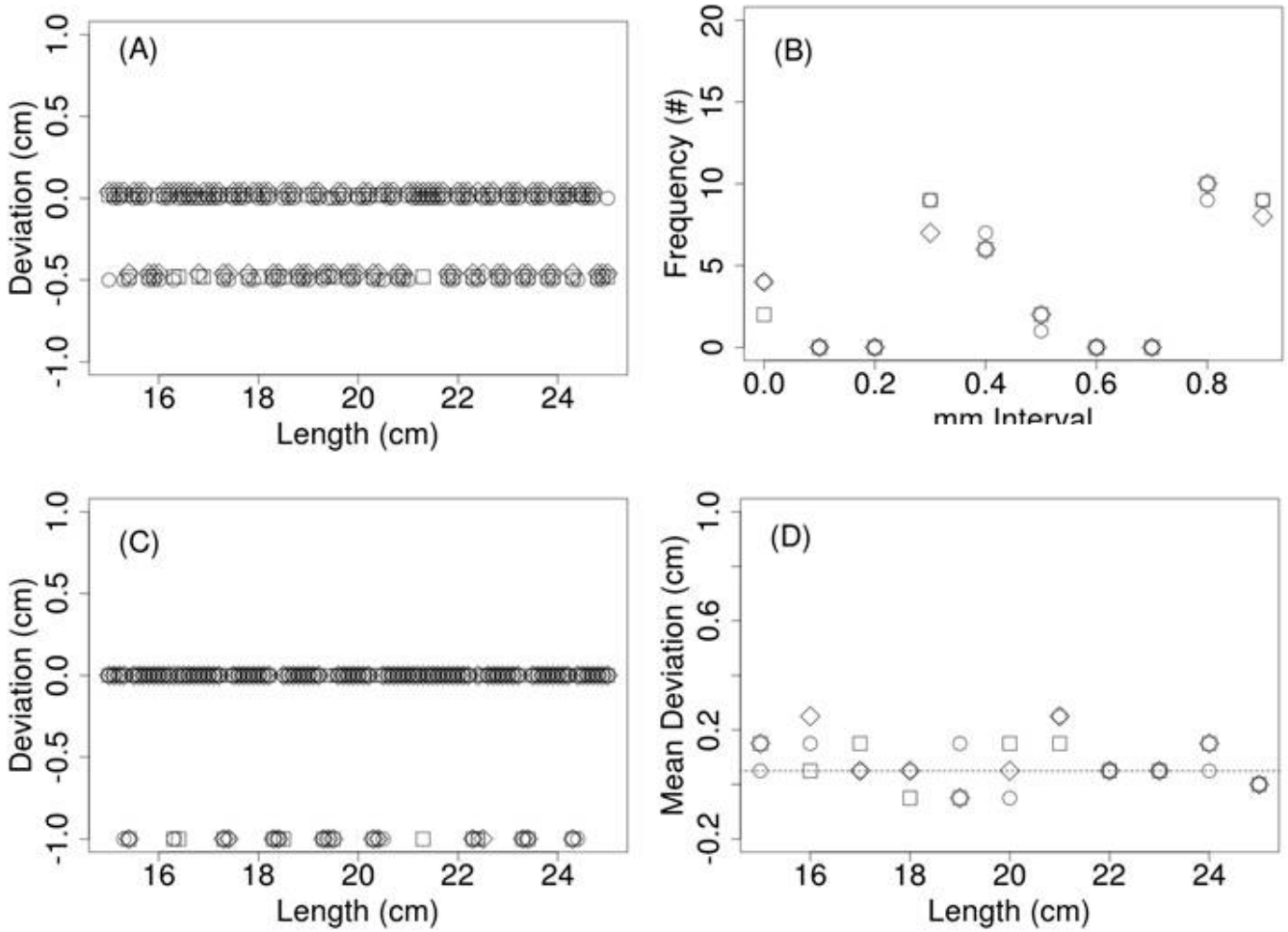

Figure 18. Fish board serial # 01-01 (FSCS equipment code: FBD00100005). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The dashed line at 0.05 cm is the nominal mean deviation for Type A Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

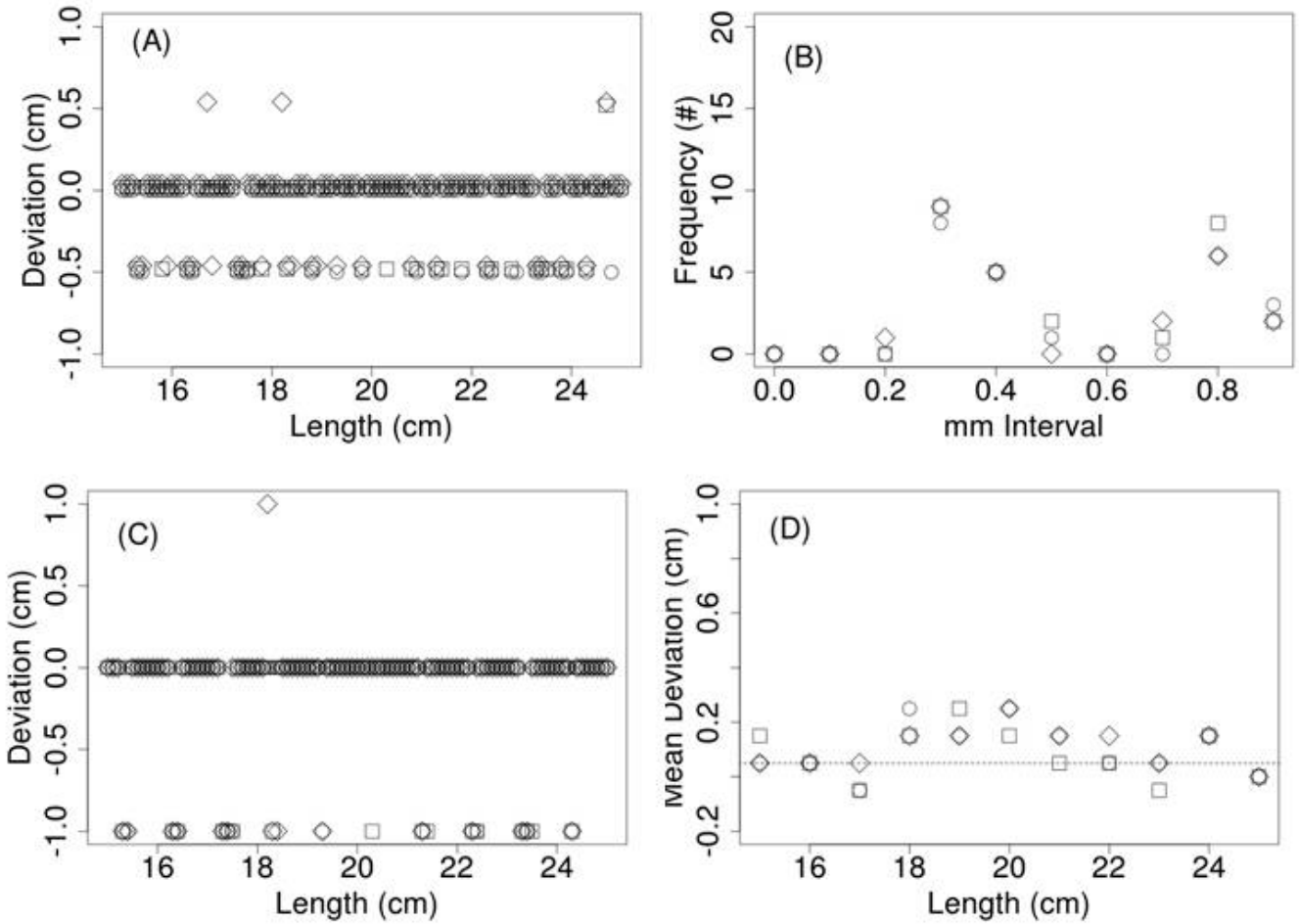

Figure 19. Fish board serial # 2126 (FSCS equipment code: FBD00100012). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The dashed line at 0.05 cm is the nominal mean deviation for Type A Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

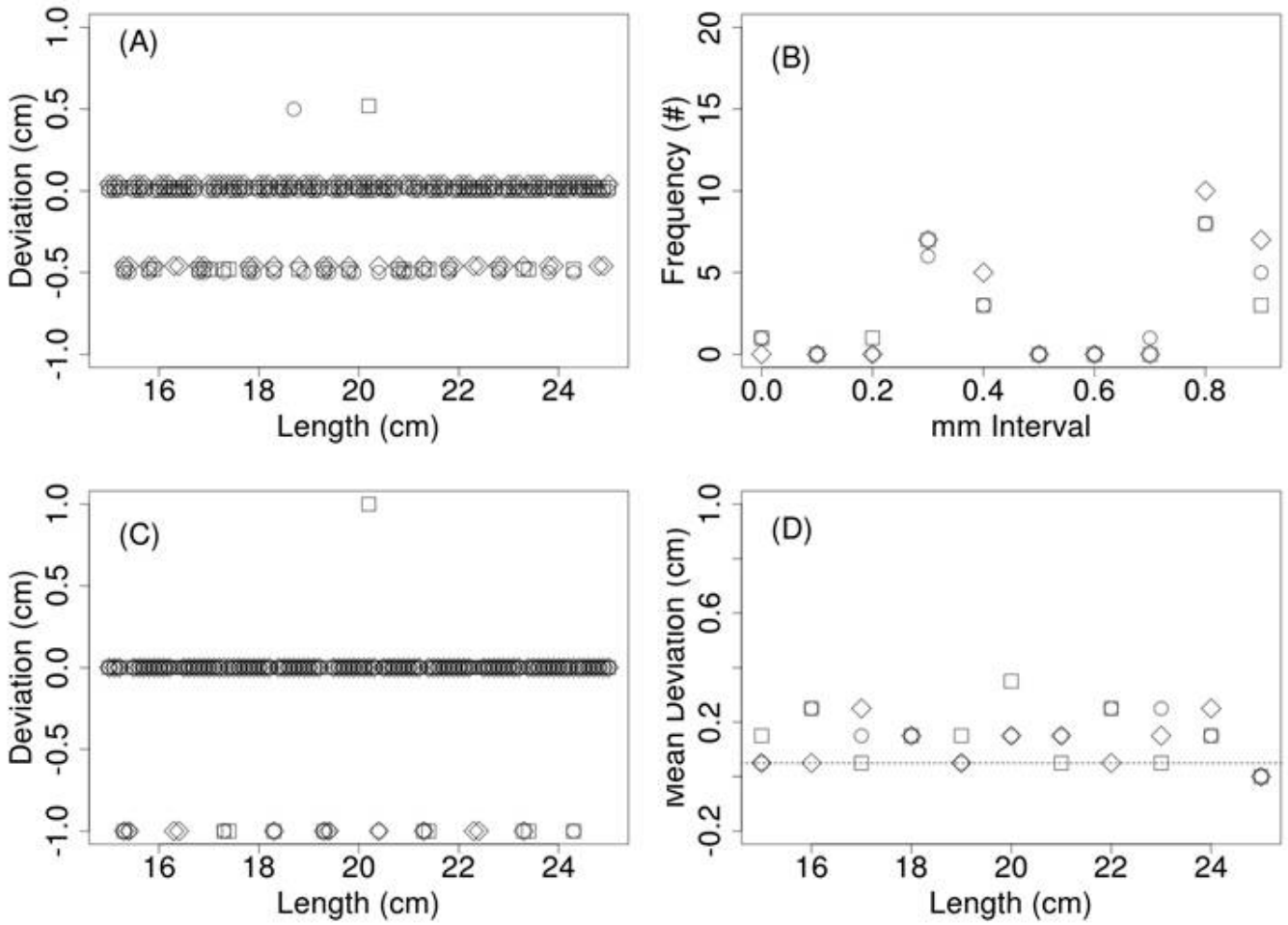

Figure 20. Fish board serial # 2127 (FSCS equipment code: FBD00100013). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The dashed line at 0.05 cm is the nominal mean deviation for Type A Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

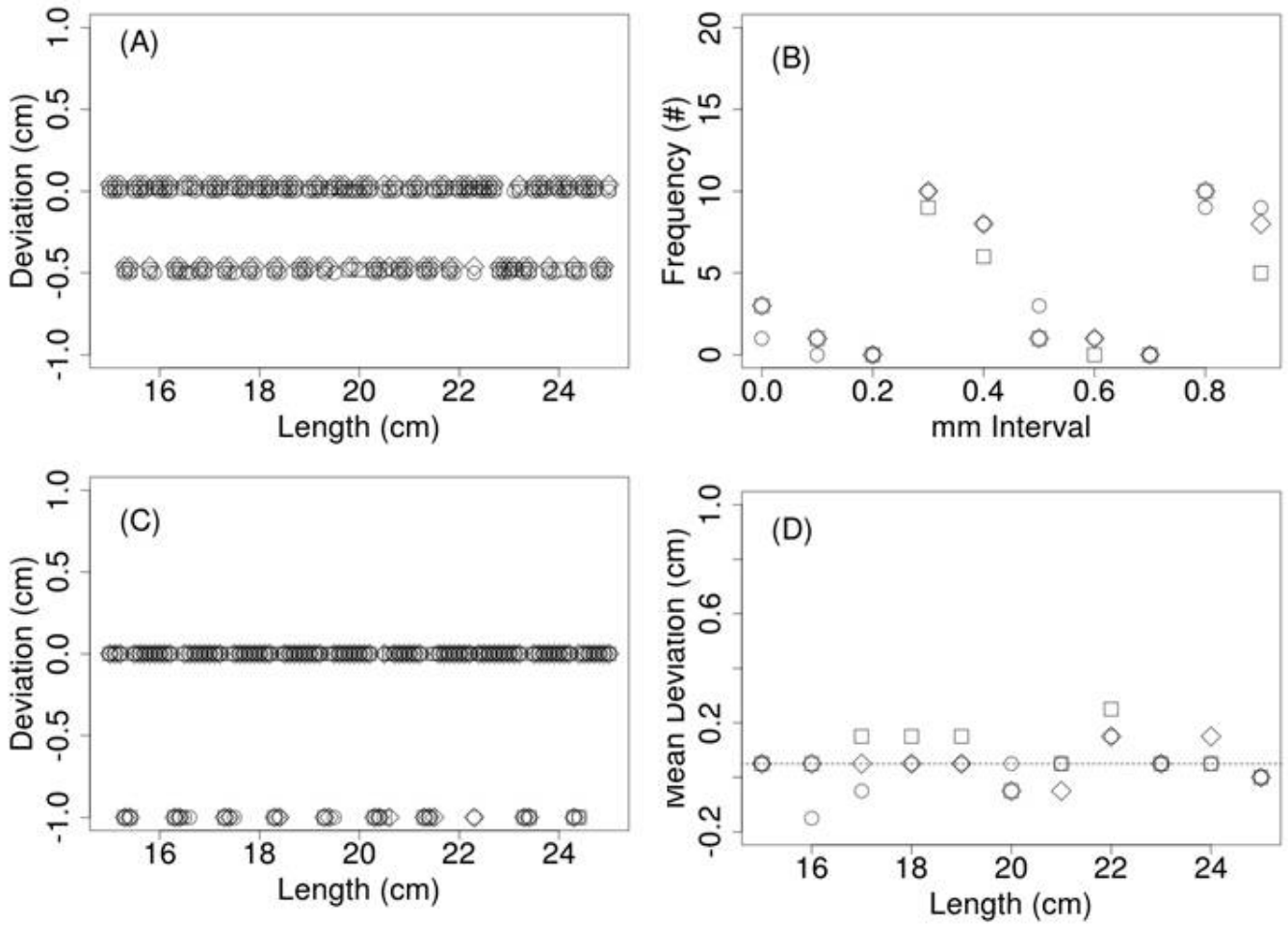

Figure 21. Fish board serial # 2130 (FSCS equipment code: FBD00100014). Panel (A) shows the deviation of each measurement as recorded by the Scantrol FishMeter board to the expected value based on the known length (i.e., known length rounded to the nearest 0.5 cm). Panel (B) shows the number of deviations (Panel A) per millimeter interval. Panel (C) shows the deviation of each measurement as recorded by FSCS to the expected value based on Scantrol rounding to the nearest 0.5 cm and FSCS rounding. Panel (D) shows the mean deviation per centimeter interval of the measurement recorded in FSCS to the known length. The dashed line at 0.05 cm is the nominal mean deviation for Type A Scantrol boards. Open circles denote the first measurement set, open squares denote the second measurement set, and open diamonds denote the third measurement set for all panels.

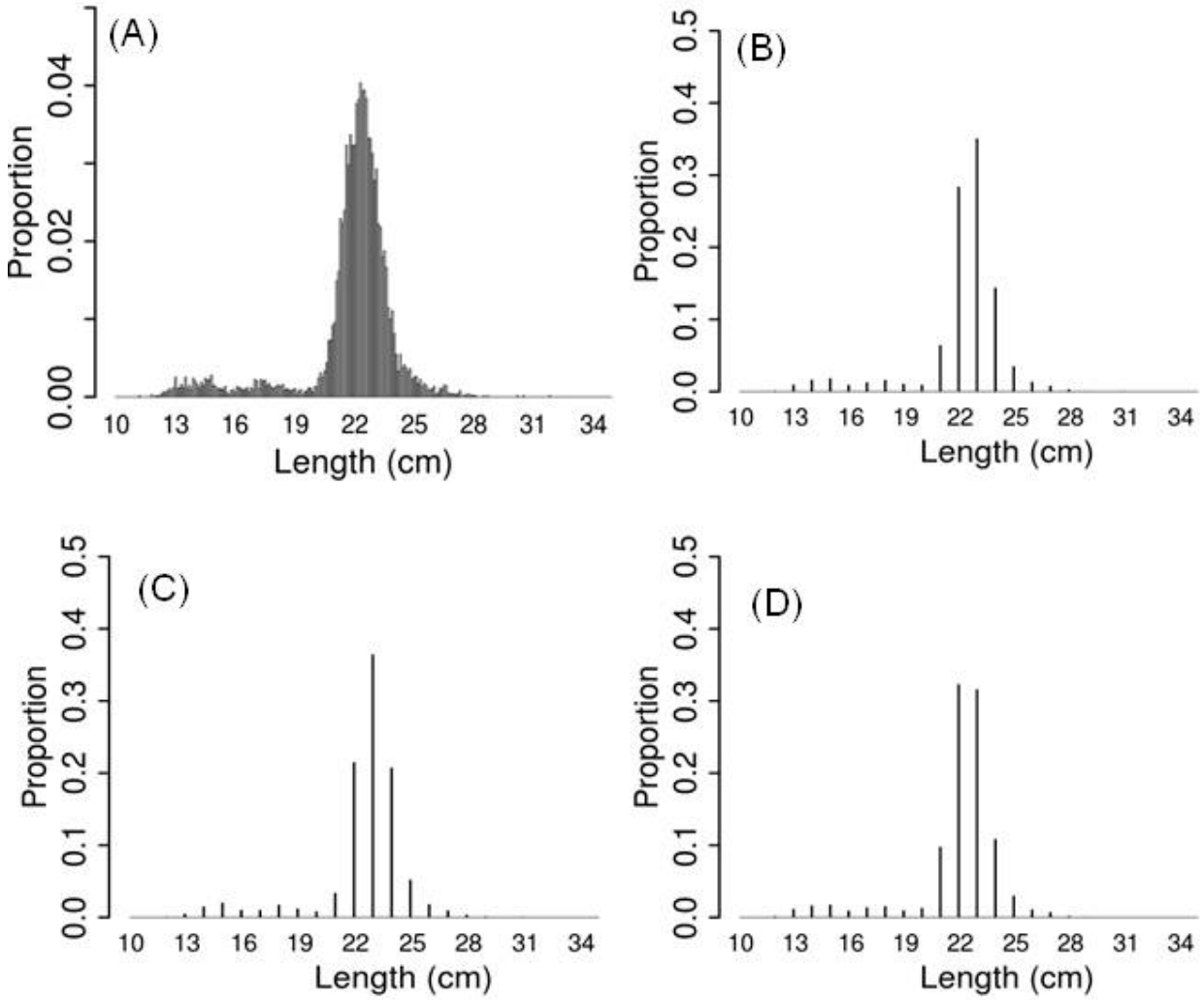

Figure 22. Probability distributions of Atlantic herring (*Clupea harengus*) fish lengths (n=7512) from midwater trawl catches in the Gulf of Maine during the systematic herring survey in 2012. Panel (A) is the distribution of original fish lengths stored in Fisheries Scientific Computing System (FSCS) in 0.1-cm resolution. Panel (B) is the distribution of fish lengths after the fish lengths have been rounded to the nearest 0.5 cm (Scantrol FishMeter rounding algorithm) and then rounded to the nearest integer centimeter (FSCS algorithm). Panel (C) is the distribution of fish lengths after rounding to the nearest 0.5 cm, adding 0.5 cm to measurements in the length intervals x.00:x.24 and x.50:x.74 (round up), and rounding to the nearest centimeter. Panel (D) is the distribution of fish lengths after rounding to the nearest 0.5 cm, subtracting 0.5 cm to measurements in the length intervals x.25:x.49 and x.75:x.99 (round down), and rounding to the nearest centimeter.

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